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STUDY AND EVALUATION OF CURRENT AND FUTURE AIRCRAFT LOADERS

Prepared For:
HEADQUARTERS, MILITARY AIRLIFT COMMAND
Scott AFB, Illinois

Under Contract No. F11623-85-C0062

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AUGUST 1986

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Section 1

INTRODUCTION

This Study and Evaluation of Current and Future Aircraft Loaders was conducted by Southwest Mobile Systems Corporation, St. Louis, Missouri, for the USAF Military Airlift Command, Scott AFB, Illinois under Contract F11623-85-C-0062.

1.1 PURPOSE

The purpose of this study is to develop performance requirement(s)/parameters that will identify future cargo handling equipment needs and specifications that will enable the Air Force to procure an advanced state-of-the-art aircraft transporter loader. This "loader of the future" will be required to interface with both commercial and military air cargo systems of the present and future. The study/analysis/evaluation, presented in this report, will outline current loader and cargo handling deficiencies along with recommendations to eliminate the deficiencies and arrive at a loader capable of working all military cargo aircraft as well as appropriate commercial aircraft. (SDU) 4 -

1.2 OBJECTIVES

This final report and a formal oral presentation provides the following:

1. Optimum performance parameters for an aircraft transporter loader based upon the determination of present and future aircraft loader requirements.
2. Rationale for the selection of the parameters.
3. Recommendations to eliminate deficiencies discovered within the current cargo handling system.

1.3 THE STUDY PLAN

The program plan consisted of three phases:

- Data Collection Phase
- System Engineering Phase
- Final Report

1.3.1 Data Collection Phase

This first part of the program served as the input to establish system requirements for the engineering analysis phase. Data relevant to the subject matter was identified, compiled and catalogued to serve as input for definition of the mission (objectives) requirements, operational environment and system constraints. Data was obtained by the following activities:

1.3.1.1 Literature Search. A comprehensive review of Air Force and commercial published documents, reports, papers and articles, commercial equipment and aircraft manuals, technical publications and military and commercial standards, and handbooks and manuals yielded a data base of relevant literature. These are listed in Appendix E.

1.3.1.2 Field Research. Field research emphasized on-site surveys and observations of actual USAF air cargo handling operations and workshops which were designed to provide Military and Government personnel the opportunity to have interactive, across-the-table dialogue for data exchange and input. These workshops were structured to provide: (1) A briefing to outline the scope of the program and the subject items for data exchange and input, (2) question/answer sessions, (3) a working session, which provided worksheet questionnaires for participants to input data to the study at the end of the

sessions. Additional questionnaires were provided to participants for completion and submittal at a date subsequent to the workshops. These additional questionnaires were also intended for use by members of participating organizations, who could not attend and were used for that purpose. Table 1-1 provides a list of workshops which includes date, location and participation representation.

On-site surveys provided hands-on observations and surveys of cargo handling operations at MAC and ALC bases. Table 1-1 lists those workshop locations where on-site surveys were conducted subsequent to the workshops. The advantage of this schedule arrangement was that Air Force workshop participants were the same personnel involved in the operations surveyed. The awareness and familiarity with the study program substantially enhanced the quality of definition and detail of explanation of operations procedures and equipment and the advantages/benefits or deficiencies/problems with them. On-site survey locations and participation are also contained in Table 1-1.

A third element of field research included on-site surveys of commercial air freight operations and data gathering sessions with commercial and military aircraft manufacturers, (Table 1-2). Four airfreight terminals were visited and actual, real-time cargo operations were observed. These operations included aircraft loading/unloading and terminal operations. Data gathering with commercial and military aircraft manufacturers dealt primarily with aircraft cargo systems, cargo handling equipment and procedures. The visit to Douglas Aircraft covered the C-17 primarily, particularly the loader/aircraft interface.

Section 2.0 of this report is a statement of the system requirements for military air cargo transport. As such it defines the mission requirement of a future aircraft transporter loader by identifying the system elements. These include the cargo types, the material handling equipment, the aircraft and

Table 1-1 List of Workshops

<u>Date</u>	<u>Type</u>	<u>Location</u>	<u>Representation</u>
22 Oct 85	Workshop	Scott AFB, IL	HQ MAC/LGTX/LNA/TRA/TRKO/TRX/TRXF/T RXM/XP-ACRA/XPQA/XPOC/XOSX/XPSS, 22AF/TRXF, HQ AFLC LOC/CFWS, WR-ALC/MMTRA, HW USAF LWTN/ AFSCA, HQ TAC/LTGA NROC/ STRNG-UAS, USA ABNSCOT, ATSP-CO-CS, ATZL-CAI-A.
18 Nov 85	Workshop	Wright-Patterson AFB, OH	HQ AFLC/MMII, LOC/TLWS. DSTMV, LOC/CFWS, OSTE/MI, ASD/ENEGF, MMII, LOC/CFWS, ASD/ENCA, DSTMA, LS/DNT, LOC/CEWA, XQLC.
19, 20 Nov 85	Workshop	Pentagon, WDC	HQ USAF/LETC/RDQL/LEYS (EDS), LET/LEYW/XOOTA/LETN, OJCS/J4, DAMOOFDQ, OASD/E&L, HQ USMC/ LME-1, USNEFG.
21 Nov 85	Workshop	Warner-Robins ALC Robins AFB GA	WR-ALC/MMTRA/MMTV/OSTA/ MMTV/SAC-OL/MMTRBV/MMSREA/ MMTVDA.
11, 12 Dec 85	Workshop & On-Site Survey	Dover AFB	436 TRANSP/LTFM, 436/APS, 436 APS/TRO/TROO, 21AF/TRXF.
29 Jan 86	Workshop & On-Site Survey	Little Rock AFB, AR	2 MAPS/TRM/TRMC/TRMV/ TRMC, 22AF/TRXF/TRP, 314 TRANS/LTFM.
30 Jan 86	Workshop & On-Site Survey	Kelly AFB, TX	SA ALC/DST/DSTA/DSTAB/DSNE/ DSMPB/DSTOM/DFTA, 363 DAW/DOXL 2851 ABG/TD.
21 Mar 86	Workshop	Scott AFB, IL	HQ MAC/XPQA/XPQC/XPW/XPSS/XPSR/ XOSA/XOSX/XOXA/TRXF/TRXP/LGTV/ LGTX/DOXT/, ASF/AEGA.
24 Apr 86	Workshop & On-Site Survey	Scott AFB, IL	HQ MAC/TRX/TRXF/LGT/LGTV/LGSW/ LS-R.
29, 30 Apr 86	On-Site Survey	Ft. Bragg/Pope AFB NC	HQ MAC/LNA/TRXF, USA ABNSOT.

Table 1-2 List of Field Trips

<u>Date</u>	<u>Locations</u>
15 Oct 85	TWA Freight Terminal Lambert Int'l Airport, St. Louis, MO
22 Nov 85	Lockheed - Georgia Aircraft Co. Marietta, GA
13 Dec 85	Flying Tigers Airlines JFK Airport, NY
10 Feb 86	Boeing Military Airplane Co. Boeing Commercial Airplane Co. Seattle, WA
11 Feb 86	Korean Airlines LAX, CA
12 Feb 86	Douglas Aircraft Co. Long Beach, CA
14 Feb 86	Flying Tigers Airlines LAX, CA
10 Apr 86	Natick R&D Center Natick, MA
11 Apr 86	Shelter Systems Development Office Hanscom AFB, MA

aerial ports used. For each of these elements, both current and future plans are included. General and, where possible, peculiar operating environment and constraints, which ultimately impact, limit or dictate the performance of a loader, are also identified. In defining the system, the deficiencies of the system become apparent and are included in Section 2.0.

1.3.2 System Engineering Phase

The analysis methodology used for the program is similar to a typical system engineering process. In the classic sense, the overall systems process deals with the system from inception (input requirements) to final development, providing for a network of actions including input requirements, function analysis, synthesis, evaluation and decision and description. In actual application these steps are interactive and interdependent.

The purpose of this study is to establish performance requirement(s)/parameters for a future aircraft transporter-loader. These analysis activities then necessarily fall within the functional analysis step and deal specifically with development of functional performance requirements. These requirements represent the acceptable level of performance for the accomplishment of identified functions.

The total systems process is an iterative process performed by trade-off studies of synthesized concepts and evaluations directed to optimization for the final system description.

This study exercise is the functional analysis step of the overall system process, which will ultimately develop the aircraft transporter loader. But the functional analysis cannot be meaningfully performed in an isolated and abstract manner, without consideration for the other essential steps.

There is a point-of-reference which serves as a basic concept and provides the synthesis input for the analysis; that's the 40K loader. To the initiated reviewer, reference to the 40K loader is almost unavoidable and this reference would intuitively serve as the synthesized concept for which trade-off evaluations would automatically follow. There are good reasons for establishing a basic concept. There are functional requirements and physical constraints of the system which require the transporter-loader to be a self-propelled vehicle with an elevatable roller-conveyer system. This concept is discussed further in Section 4.1.

By using this basic concept, the performance requirements established are explained and perceived more readily. Reference to a concrete, real concept aids the system process and minimizes the possibility of abstract definitions of functional performance requirements. A second benefit is that established performance requirements can be better understood and evaluated in regard to eliminating deficiencies of the current cargo handling system. The system analysis is contained in the following Report Sections:

- 2.0 System Requirements
- 3.0 Function Identification
- 4.0 Performance Requirements Analysis
- 5.0 Evaluation

1.3.3 Final Report and Briefing

This report serves as the final step in the Study Plan.

Section 2

SYSTEM REQUIREMENTS

The definition of the "role" of the Aircraft Transporter-Loader (ATL) in the military air cargo handling system is an initial and essential element of the study analysis. By means of the Data Collection Phase, input data has been received and organized to permit definition of the function and functional requirements of the ATL, i.e., the "mission" of the ATL in the military air cargo handling system.

The complete statement of the system requirements also provides for definition of the operational environment conditions in which the ATL must operate, and identification of the system constraints which affect the configuration and characteristics of the ultimately derived ATL.

2.1 MISSION DEFINITION

In defining the total mission requirements for the ATL, both military and commercial air cargo handling systems have been reviewed and researched. The mission of the ATL in the USAF air cargo handling systems is of primary concern and interest. Although USAF aircraft loader/unloaders are not used in the commercial air cargo systems, applicability and use of similar commercial loaders have been researched to determine if there are performance and procedural features that may be advantageous and beneficial in the military air cargo handling system.

2.1.1 Military Air Cargo Handling System

The military air cargo handling system in which the ATL will operate is the system related to cargo airlift operations of:

- The Military Airlift Command (MAC)
- All commercial contract cargo airlift services derived from the Civil Reserve Air Fleet (CRAF)
- Cargo airlift operations of the Strategic Air Command (SAC) and the Tactical Air Command (TAC)

The main element of the system is MAC and CRAF contract airlift operations. The CRAF is composed of U.S. civil air carriers who are contractually obligated to provide aircraft and operating personnel and facilities to MAC. It makes available commercial airlift resources for both peacetime and wartime augmentation of organic military airlift capability. The CRAF airlift capability can be activated incrementally in three stages:

- Stage I - Committed Expansion. This is airlift capability, from the long-range international segment, committed to Commander in Chief MAC. It can be used to perform airlift services when the MAC airlift force cannot meet both deployment and other traffic requirements simultaneously. Commander in Chief MAC has the authority to activate Stage I of CRAF.
- Stage II - Defense Airlift Emergency. This is an additional airlift expansion identified for an airlift emergency not warranting national mobilization. The Secretary of Defense has the authority to activate Stage II of CRAF.
- Stage III - National Emergency. CRAF Activation. This is the total CRAF airlift capability made available when required for DOD operations during major military emergencies involving U.S. forces. The Secretary of Defense will issue the order to activate Stage III of the CRAF only after a national emergency has been declared by the President or the Congress of the United States, or under specific conditions requiring Stage III capability.

Stage I management of CRAF resources is primarily the responsibility of HQ MAC/XPW. In Stage II and III, management of CRAF is accomplished by the MAC crisis action team (MAC CAT). Aircraft allocated to CRAF are assigned to each element of CRAF based on wartime tasking. The four elements of CRAF consist of:

- The Long and Short-Range International segments both managed by MAC CAT and HQ MAC/XPW.
- The Domestic segment, consisting of LOGAIR managed by the U.S. Air Force Logistics Command (AFLC)
- QUICKTRANS managed by the Naval Supply System Command (NAVSUPSYSCOM)
- The Alaskan segment managed by the Alaskan Air Command (AAC)

An important feature of the MAC and CRAF system is aircraft allocation. CRAF participants are contractually obligated to insure the availability of aircraft assigned and allocated in the CRAF agreement. In addition to the principal considerations for range, payload, and configuration, cargo aircraft must be equipped with cargo handling systems compatible with the military 463L pallet. CRAF aircraft augment MAC's organic aircraft assets, consisting of the C-130, C-141B, and the C-5.

The KC-10A, which is primarily intended to provide in-flight refueling capability, also serves as a cargo airlifter for SAC, TAC and MAC. As such, cargo handling operations for this aircraft are included in the military air cargo handling system, in which the ATL must operate.

2.1.1.1 The MAC Airlift System. MAC's primary mission is the deployment of combat forces to distant and varied locations throughout the world. This capability is derived from the fundamental Air Force capability -- rapid long-range mobility by airlift. This airlift capability consists of two distinct functions: strategic airlift and tactical airlift.

Strategic airlift provides long-range air transport of personnel and materiel between areas of command which is usually intercontinental. This inter-theatre airlift is characterized by an infrastructure which requires scheduled routes, continuous movement of large cargo volume and use of aircraft with large cargo capacity, which can fly intercontinental distances. The C141B, C5 and wide-bodied and long range narrow bodied CRAF aircraft currently provide this service. Aerial ports of embarkation (APOE) and debarkation (APOD) for strategic airlift are typically main operating bases (MOBs). MOBs are characterized as having unrestricted runways, wider taxiways and parking areas for servicing large, intercontinental aircraft and mechanized air freight facilities with a full complement of material handling equipment (MBE) adequate to interface with the total airlift force (including CRAF).

The MOB characteristics result from the airlift aircraft and airfield relationship. The C-141B, C-5 and large CRAF aircraft are restricted to larger airfields which can accommodate their performance capabilities, i.e., landing and takeoff distances, taxiway and parking requirements, etc. Being large cargo volume haulers, they require mechanized cargo handling systems and a full complement of MBE to load/unload the diverse types of cargo transported by these aircraft.

These same airfield requirements are the limiting factor for strategic airlift in completing the full airlift mission. As final off-load bases for deployed forces move forward, available airfields become smaller and unavailable to the strategic airlift aircraft and support equipment, such as MBE, becomes limited, if not unavailable. For this reason, forward area operations is the arena for tactical airlift.

Tactical airlift, in contradistinction to strategic airlift, must be flexible. Rapid movement of troops and equipment within a theatre of operation (intratheatre) must be fluid, flexible and allow for high maneuverability. Tactical airlift operations are characterized by flexibility in response time, route structure and destination. Tactical aircraft requires maneuverability and capability to land at a complete spectrum of wartime airfields, as close to the battlefield as possible.

Although the APOE for tactical airlift will be a MOB, final off-load bases will be small austere airfields (SAAF). Runways for SAAFs will be typically too short for the larger strategic airlifters with inadequate load bearing capacity for these larger aircraft. MBE is typically limited to the 10K rough terrain forklift and TAC loader. The limited size and austere condition of the SAAF restricts tactical airlift to the C130.

Given the airlift capability, there are problems in meeting the goal of worldwide projection of U.S. military forces. These problems arise primarily from the limitations of the airlift aircraft which perform well when compared to their original design intent but have shortcomings in the current airlift system.

There are performance limitations with the intercontinental aircraft, i.e., the C-141B and C-5, in performing the tactical segment of the airlift requirement. They are too large for the forward SAAFs. There are also interface problems between the strategic and tactical aircraft at the MOBs where cargo must be trans-shipped between the larger air freighters and the smaller C-130. First, outsized cargo which can be delivered by the C-5 to tactical airlift APOEs cannot be redeployed by the C-130 because of its inability to transport out-size cargo. Secondly, even though palletized cargo (463L) is handled by all three of the MAC and CRAF aircraft, there are trans-

shipment problems due to the limited envelope size of the C-130 cargo compartment. Palletized cargo received from the C-5 and C-141B must be "repackaged" to meet the smaller envelope of the C-130.

The projected Airlift Plan of MAC will circumvent these limitations with the C17 which, in addition to having payload capacity and range to serve in the strategic fleet, will also have performance characteristics to allow direct delivery of outsized and oversized cargo directly to forward areas (SAAFs). For the purposes of this study, future requirements of the ATL include servicing (load/unload) of the C17.

The latest fleet enhancement being considered by the USAF is the Advanced Tactical Transporter (ATT). This aircraft will eventually replace the C130. Requirements for the ATT are currently being studied by HQ MAC/XPSS.

Having defined the elements of the Military Air Cargo Handling System and the MAC Airlift System, the total mission requirements for the ATL can be defined in greater detail by reviewing and defining the primary air cargo handling system developed for the USAF: the 463L Air Cargo System.

2.1.1.2 The 463L Air Cargo System. The 463L System was developed by the USAF on the premise that the key element of an effective cargo handling system is a Unit-Load Device (ULD). This ULD is the 463L (or BCU-6/E) pallet and has served as the controlling element of the entire 463L system.

The system consists of four separate, interrelated families of equipment:

- Cargo Preparation Family
- Cargo Ground Handling Family
- Aircraft Systems Family
- Terminal Facilities

Each of the families are interrelated because the system evolved around the 463L (BCU-6/E) pallet. All of the equipment in these families is designed or selected to load and secure the BCU-6/E, or a derivative of this pallet, for which the system is designed.

ATLs are included in the Cargo Ground Handling Family and, as such, are required to interface with other Material Handling Equipment (MHE) within that family and with elements of the Terminal, Cargo and Aircraft families. This is the system in which the ATL must operate and within which its mission is found.

The function of the ATL is best understood by review and discussion of elements of the system in the following sections. This is accomplished by identifying the cargo types (paragraph 2.1.3), which the ATL must transport/load/unload; the MHE (paragraph 2.1.4), with which the ATL must interface in the system; the cargo aircraft (paragraph 2.1.5), for which the ATL must transport/load/unload cargo; and the aerial port terminals (paragraph 2.1.6), within which the ATL must operate.

2.1.2 Commercial Air Freight Companies

Commercial air freighters are on the threshold of a new era. The vigorous growth in air freight traffic, currently running at an annual rate of 17% industry wide, is forcing airline management to accept the fact that pursuit of the freight business is a worthwhile objective in itself.

In 1984 small package traffic in the USA amounted to 157 million shipments, up by 36% from 1983, and produced revenue of \$3.3 billion, a 26% increase. It accounted for about a fifth of U.S domestic freight tonnage. Half of U.S. domestic freight moves in the bellies of passenger aircraft, from

which it follows that some 40% of freight on "all-cargo" flights is composed of small package consignment. The average small package weights about 7-1/4 pounds.

One of the main reasons for the change in the conventional patterns of freight transport lies in the "Just in Time" concept which originated in Japan, where production is planned from the outset for export. The cost of air freight is minimal in comparison with the cost of holding inventory, and even more insignificant when seen against the effects of running out of parts during a production run. Freight of supplies to arrive just before they are needed can produce an enormous economic advantage. Ironically, this is precisely the same situation that MAC faces during a contingency, the main difference being in the criticality of the end result.

The domestic freight market is shared by three distinct types of haulers:

- The commercial passenger airlines
- The express package hauler
- The heavy freight hauler

It is true that the types of freight carried by these haulers overlap, and in some instances, is the same, but their primary mission seems to be as defined by their grouping. Obviously, there are many other smaller freight forwarding and air cargo services available; however, for the purpose of comparing methods of material handling in this report, it is advantageous to concentrate on the leading three. A brief summation of these haulers and their generalized cargo handling methods is described as follows:

1. Commercial Passenger Airlines - In general, the airlines service the individual aircraft cargo needs at the passenger gate. Narrow bodied aircraft are predominantly loaded/off-loaded using bulk cargo and belt driven conveyors with cargo being transferred to baggage carts. The wide-bodied passenger aircraft are serviced by elevating cargo loaders, which load and off-load the lower deck containers. These

containers in turn are transferred to small dollies or carts, which are coupled in succession and towed by a tug. Each dolly is towed up to the elevator loaders and aligned along side the loader to receive its allocated container. Normally only one container is loaded on each dolly. The train of dollies and containers is then dispatched to the terminal or freight forwarding area after loading/off-loading is completed.

In those instances where the airline uses an aircraft (wide or narrow bodied) for cargo only, the loading off-loading usually takes place on the ramp in a designated cargo area. The loading/off-loading operation is the same, however, with the elevating cargo loader serving as a bridge, which transfers containers or pallets to the waiting train of dollies. Normally, the elevator loader takes one to three pallets at a time and is not effective when used as a transporter.

2. The Express Package Hauler - The express package business has always been an element in the U.S. air transport industry, but it took deregulation and the spectacular success of Federal Express and its imitators to bring it to its present state.

It is probably an over simplification to describe an express package hauler as a single dimension cargo handling identity. Generally, they can be characterized as a hauler handling huge volumes of small cargo which is mostly containerized, and is rapidly loaded/off-loaded and dispersed in specially designed terminals. These terminals are highly automated and utilize high speed transfer and scanning systems designed to minimize labor and improve handling methods. The entire handling system is somewhat reminiscent of a postal service operation where millions of small pieces of mail are handled on a daily basis.

3. The Heavy Freight Hauler - Probably the most representative of the heavy freight hauler is the all cargo airline "Flying Tigers". They tend to lean toward transfer of larger, heavier and more specialized

cargo. A significant percentage of the cargo is palletized and carried on both commercial and military pallets. Containers are frequently used and in some instances roll-on/roll-off vehicular cargo is transported. Where the commercial passenger airlines and the express package hauler are transporting large volumes of smaller packages, the heavy freight hauler is routinely transporting single loads which may go as high as 80,000 pounds. The heavy freight hauler is more likely to have a preponderance of wide-bodied freighters in the fleet of aircraft and support the fleet with terminals which may be highly automated but more likely geared to palletizing and containerizing heavy cargo.

The loading/off-loading methods used by the heavy hauler most closely approximate the system currently used by the Air Force. The aircraft is usually parked on the ramp and is served by elevating cargo loaders some distance from the terminal. Basically, the cargo loader is used as an elevating bridge which raises and lowers pallets and other related cargo from the aircraft. The bridge is normally served by one or two transporters, which can handle a small number of pallets or containers (usually one or two). These transporters are capable of relatively high speeds and essentially serve as a supply train to and from the loader and the terminal. They utilize powered roller decks, and the transporter and bridge operator become very proficient in rapid movement of cargo. It is not uncommon to load or off-load 200,000 pounds of cargo from a wide-bodied aircraft in one hour or less.

We have briefly reviewed the three major types of cargo haulers and their methods of loading/off-loading cargo. In many instances the type of cargo, the mix of aircraft and the methods of handling are similar and do overlap.

With the exception of the air express mode of cargo transfer, which use specially designed terminal systems, the accepted method of cargo transfer seems to be by "Wagon Train". This system uses a series of dollies or transporters which receive and dispatch cargo from a stationary bridge at the aircraft and in turn transfer to and from the terminal.

This method of cargo transfer has definite advantages to the commercial hauler who has fixed bases, each stocked with adequate equipment and little or no need to transfer that equipment.

Indeed, the method and principle of handling can be applied to loader techniques at some military installations where an adequate mix of transportation/loaders is available. However, when one looks at the military mission, in which it often becomes necessary to rely on single loaders which carry large numbers of pallets, travel greater distances and must be transportable on military aircraft, it becomes apparent that the commercial loading systems lack the flexibility to meet military needs.

2.1.2.1 Commercial Aircraft Loaders. Commercial cargo loaders are used to service both narrow and wide-bodied cargo and passenger aircraft. Because of the variety in aircraft, the different methods of loading/off-loading and individual terminal interface, it is not surprising that cargo loaders come in all shapes and sizes.

In order to get a representative cross section of the commercial cargo loader market, some one-hundred and sixteen models of commercial loaders, both foreign and domestic, have been reviewed. In general, these loaders fall into three broad categories:

- **Elevator Loaders** (See Figure 2-1) used to lift or lower cargo to and from the main deck of aircraft. These loaders consist of four vertical posts with a platform in the center that can be raised and lowered by cables. Other equipment is required to transport cargo to and from the elevators.
- **Mobile Loaders** (See Figure 2-2) differ from elevators in that the platform is raised by a scissors mechanism rather than by cables and

corner posts. Mobile loaders quite commonly utilize a split deck arrangement in which the loading deck is divided into two separate platforms, each elevated by a hydraulically operated scissors mechanism.

The front or shorter platform is located above the vehicle power train and/or the drivers cab. This platform aligns with the aircraft door sill and is used as a transfer device. Vertical travel is limited, as the platform cannot be lowered to service lower lobes, etc., because of interference with the vehicle power train.

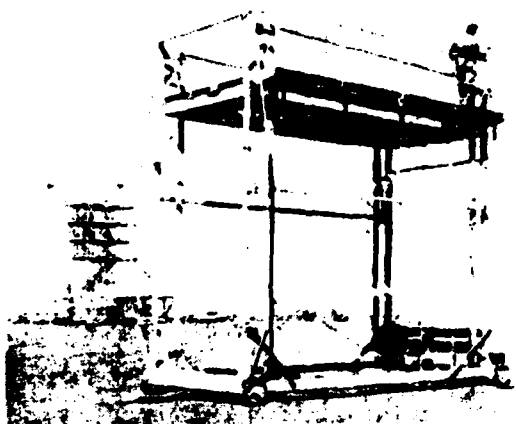


Figure 2-1 Elevator Loader



Figure 2-2 Mobile Loader



Figure 2-3 Transporter Loader

The rear or longer platform aligns with the front platform and cargo is transferred from the aircraft to the front platform and then to the rear platform. The rear platform is then lowered and cargo is transferred to other equipment for transport to the terminal. Basically, the front platform serves as a bridge from the aircraft to the rear platform, which serves as an elevator to raise and lower cargo. Usually the front platform can accommodate one commercial pallet (96 inch by 125 inch) and the rear platform can accommodate two pallets.

These mobile loaders are not normally designed to be transporters. Although they are self-propelled and some models have limited transport capability, other equipment is usually required to transport cargo to and from the loader.

- Transporter Loaders (See Figure 2-3) have the combined capability of both transporters and loaders. Essentially a truck with the ability to raise and lower the truck bed to interface with aircraft, they are used to transport cargo to and from the aircraft as well as to load and off-load.

In actual service, transporter-loaders are more suited to military use rather than commercial. Commercial aircraft are usually parked close to a terminal and therefore the loader is primarily used as an elevator and cargo is transferred rapidly to a waiting train of cargo carts or dollies.

Military aircraft, on the other hand, are often parked a considerable distance from the terminal, if indeed a terminal exists, and the loader must often serve as an elevator to load/off-load cargo and then transport this cargo some distance to a designated area.

Because most transporter-loaders are designed to service the lower cargo door heights of military and narrow bodied aircraft, it is unusual for this type of loader to have the capability of servicing the higher main decks of wide-body aircraft.

In order to evaluate the large variety of commercial loaders in terms of required military usage, it was decided to assume five basic criteria elements against which each loader could be measured. These criteria elements and the rationale for selecting them are as follows:

1. Elevator Range - Since the CRAF uses a number of wide-bodied aircraft, it is realistic to expect a large capacity loader to service these aircraft. Therefore, only those loaders capable of reaching the main decks of these aircrafts were considered.
2. Capacity - The current 40K loader is capable of lifting and transporting 40,000 pounds. It is anticipated that a reduction in lift capacity is not desired in the large capacity loader; therefore, only loaders with the approximate capacity or greater were considered.
3. Transporter-Loader - Current Air Force practice is to utilize the cargo loader to load/off-load the aircraft and to shuttle cargo to and from a designated marshalling area. Transporter-Loader capability was considered necessary.
4. Apparent Availability - Loaders which are currently being built and are in service are considered in lieu of conceptual designs which are not yet hardware.
5. C-141B Air Transportability - For the purpose of this study, air transportability is defined as equipment and cargo which can be carried in an aircraft with not more than minor dismantling and reassembly.

The current 40K loader is air transportable in a C-141B aircraft even though excessive preparation and shoring is required and clearance requirements must be waived. It is anticipated that a future large capacity loader must be air transportable in the C-141B and must be loaded in conformance with wheel loading and clearance criteria, along with other requirements as outlined by AFSC Design Handbook DB 1-11.

Table 2-1 is a summary of commercial cargo loaders which most closely met the foregoing criteria for a large capacity loader. Of the 116 models of cargo loaders reviewed:

- Twelve models met the criteria of lifting capacity (40,000 pounds), elevating range (18 feet) and apparent current availability. Of these 12 units, one was an elevator loader and 11 were mobile loaders with 8 of these utilizing a split deck and 3 using a single platform.
- No transporter-loaders met the criteria of lifting capacity (40,000 pounds), elevating range (18 feet) and availability.
- None of the 12 models of cargo loaders evaluated met the criteria of air transportability in a C-141B as defined in this section.

In addition to the loaders evaluated, two proposed new loaders were reviewed. These units are still in the conceptual stage and performance expectations, as defined, remain to be realized. However, the units are included in this section as an additional informational input. These loaders are included in Table 2-1 and are:

1. The Avialift Super Hylo Military Transportable Cargo Loader proposed by Avialift of England (See Figure 2-4).
2. BMA Transporter Loader HBS 300 proposed by Braunschweigische Maschinenbauanstalt of West Germany (See Figure 2-5).

The requirements for a military cargo loader differ markedly from those for commercial loaders. The principle difference lies in the mission each is required to accomplish. Basically, commercial loaders function as elevators interfacing between the aircraft and additional support equipment, which transfers cargo to and from the aircraft.

Military loaders perform the dual function of both elevator and transporter delivering cargo to and from the aircraft as well as loading/off-loading the aircraft. There are many features of commercial loaders which can be incorporated in the development of a military loader, but the fact remains that the needs of commercial airlines are not consistent with the military mission.

Table 2-1 Commercial Cargo Loader Characteristics (Page 1 of 3)

MANUFACTURER/MODEL COUNTRY	DESCRIPTION	ELEVATING RANGE	CAP. X 1000 LBS. LBS.	PLATF. WIDTH	MAX. PALLET SIZE	PLATF. LENGTH	NO. PAL	UNIT DIMENSIONS	UNIT WT. X 1000 lb. UNLAD.	C141 AIR TRAN
Air Marrel* Lam 2000 DP/B6 France	Mobile Loader Split deck 2 platforms	18.2' max 6.9' min	44	10.5'	96" X 125"	21.2' & 8.2'	2	32.8" L X 15.4" W X 10.5' H	48.5	No
Air Marrel* 316 France	Elevator Loader 4 Post cable Lift, Single platform	18' max 1' -8" min	40	10' -8"	96" X 125"	21' -4"	2	23" -3" L X 16' -10" W X 20' -8" H	17.5	No
Trepel AG* PCL 200/56 Germany	Mobile Loader Split deck 2 platforms Scissors type	18.2' max 1.7" min	44	-	96" X 125"	-	-	40.4' L X 12.5' W X 6.2' H	66	No
Zippo GmbH* HBPC-180B Germany	Mobile Loader Split deck 2 platforms Scissors type	18.2' max 1.7' min	39.7	10.8'	96" X 125"	21' & 14.1'	-	37.7' L X 12.98' W X 10.5' H	49.6	No
Zippo GmbH* HBPC German	Mobile Loader Single deck Scissors type	18.2' max 1.7' min	29.7	10.8'	96" X 125"	21'	-	27.2' L X 11.5' W X 6.5' H	22	No
Avioquei* 2P1500	Mobile Loader Split deck 2 platforms Scissors type	18.2' max 1.6' min	39.7	11.5'	96" X 125"	22.5' & 13'	2	40.34' L X 14.76' W	55	No

NOTE: * All units are self-propelled diesel. All units service normal range of commercial narrow-bodied aircraft.

Table 2-1 Commercial Cargo Loader Characteristics (Page 2 of 3)

MANUFACTURER/MODEL COUNTRY	DESCRIPTION	ELEVATING RANGE	CAP. X 1000 LBS.	PLATF. WIDTH	MAX. PALLET SIZE	PLATF. LENGTH	NO. PAL	UNIT DIMENSIONS	UNIT WT. X 1000 lb. UNLAD.	CL41 AIR TRAN
Cella SpA AS145/205 Italy	Mobile loader Split deck 2 platforms Scissors type	10.2' max 1.7' min	44	-	96" X 125"	-	-	-	-	No
AVIALIFT* Super Hylo 18 M England	Mobile loader Split deck 2 platforms Scissors type	18' max 1.6' min	44	-	96" X 125"	-	2	35' L X 15' W	65.3	No
FMC* MDL-40 USA	Mobile loader Split deck 2 platforms Scissors type	18' -4" max 1' -7" min	40	10' -8"	96" X 125"	23'-3" & 14'-2"	-	39' -5" L X 14' -8" W X 12' -6 1/2" H	65.7	No
FMC* MDL-60 USA	Mobile loader Split deck 2 platforms Scissors type	18' -4" max 1' -7" min	60	10' -8"	96" X 125"	21'-3" & 14'-2"	-	40' L X 14' -8" W X 12' -6" H	85	No
TRANSACT* TA 40 USA	Mobile loader Single deck Scissors & cylinder type	18' max 1' -8" min	40	10' -9"	96" X 125"	22' -8"	-	27" -8" L X 12' -7" W X 11' -11" H	-	No
TRANSACT* TA 72 USA	Mobile loader Single deck Scissors & cylinder type	18' max 1' -8" min	72	12' -2"	96" X 125"	32' -1"	-	40' -11" L X 13' -6" W X 11' -11" H	63	No

NOTE: * All units are self-propelled diesel. All units service normal range of commercial narrow-bodied aircraft.

Table 2-1 Commercial Cargo Loader Characteristics (Page 3 of 3)

MANUFACTURER/MODEL COUNTRY	DESCRIPTION	ELEVATING RANGE	CAP. X 1000 LBS. LBS.	PLATF. WIDTH	MAX. PALLET SIZE	PLATF. LENGTH	NO. PAL	UNIT DIMENSIONS	UNIT WT. X 1000 lb. UNLAD.	C141 AIR TRAN
NOTE: The following cargo loaders are proposed for development and are still in conceptualization stage - Performance expectations as defined remain to be realized.										
AVIALIFT* SH-401 England	Transporter loader Single deck Scissors type	18' -4" max 3' min	44 5 66	-	88" X 108"	-	3	25" L X 8' -10" W	36	C130 6 C141
BMA* HBS 300 Germany	Transporter loader Single deck	18' max 3' -7" min	66	10' -5'	88" X 108"	40' -0"	5	-	55	?

NOTE: * All units are self-propelled diesel. All units service normal range of commercial narrow-bodied aircraft.

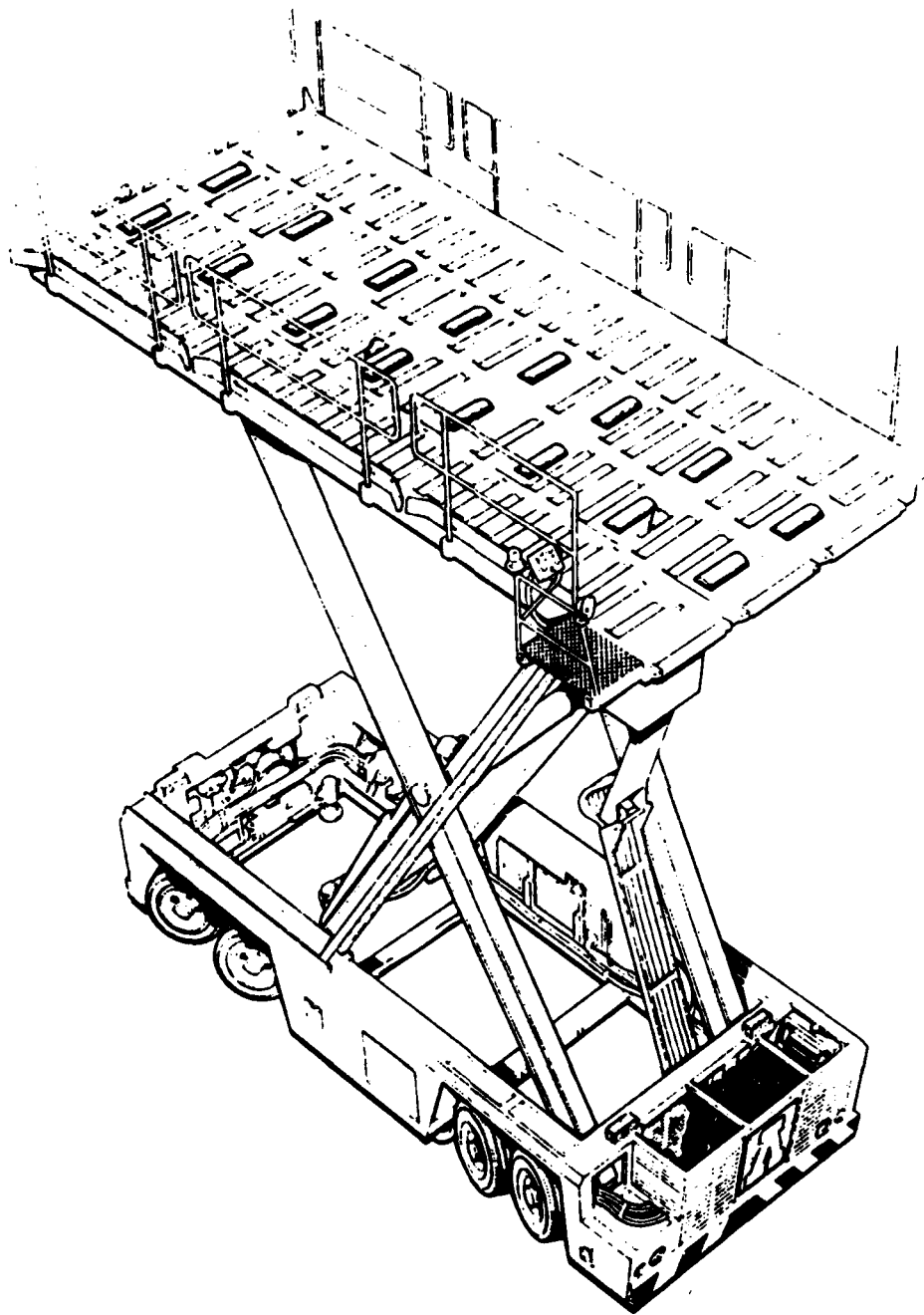


Figure 2-4 Avialift SH-401

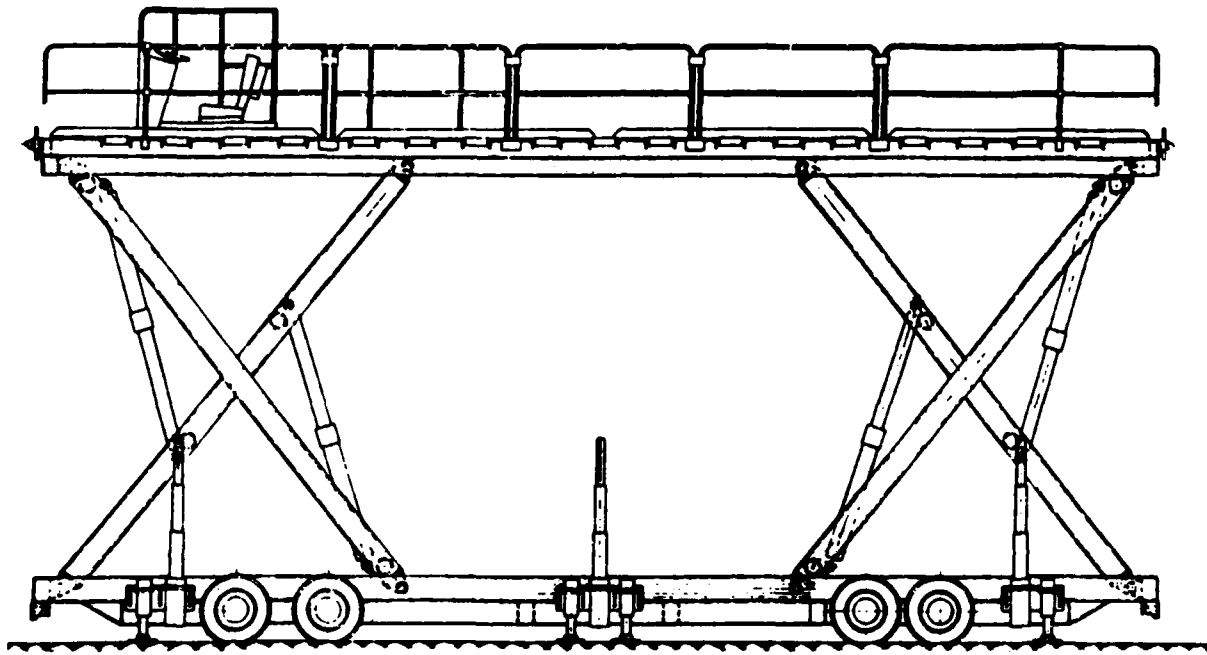


Figure 2-5 BMA Transporter Loader, Model HBS-300

Commercial loaders can be used on a limited basis in the military environment, but during a full scale contingency, or in order to achieve maximum use on a daily basis, it would appear that the military needs a cargo loader of its' own, designed and built to meet specific USAF requirements.

2.1.3 Cargo Types

Efficient use of air transport is based on unitization of cargo. This concept of unitization emphasizes the consolidation of cargo to a single load element that can be handled and transported through the distribution system with minimized repetitive handling of cargo. In an air transport system, the configuration and load capacity of the ULDs (pallet, containers, etc.) follow from the aircraft cargo compartment size and payload. Improved efficiency results from standardizing the ULDs and selection or design of material handling equipment, compatible with the ULD (size and weight) and the aircraft.

MAC airlift delivery is accomplished either by airland or airdrop. Airland is the preferred mode, because it is the safest and most dependable delivery method.

Cargo delivered in the airland mode is unitized on pallets, platforms and containers or rolling stock, which is drive-on/drive-off. Airdrop mode cargo is unitized on airdrop platforms or by the Container Delivery System (A22 containers). The various forms of cargo unitization are discussed below. These are the cargo elements which the ATL will be required to handle.

2.1.3.1 Pallets. The need for a specialized loading system for airlift was first officially recognized by the USAF with Specific Operational Requirement No. 157 (1951) and the Douglas Aircraft Company Study (1960), which defined the 463L System. Previous to this study effort, Douglas had developed a rapid loading system for the C-133 based on preloaded plywood pallets; Lockheed Aircraft Corp developed a similar pallet system for the C-130.

The important and far-reaching conclusion made in this study(ies) is that the pallet (or platform) is the key element to an effective cargo handling system. The pallet concept:

1. Minimizes manual handling of break-bulk cargo and transfers the labor-intensive function of cargo preparation to more efficient terminal facilities prior to aircraft availability and loading.
2. Provides a rigid structure suitable for rapid handling with roller conveyor systems on aircraft and MHE.
3. Provides a standard system for restraining and locking cargo on these roller conveyor systems.

The concept was born out of emphasis of maximized efficiency, by minimizing the amount of manual handling of break-bulk cargo.

The study also provided for interoperability with both military and commercial aircraft (in use or in development at that time) and intermodality with surface carriers (flat-bed trucks, railway cars and van containers). The pallet size of 108 inches by 88 inches was a consensus decision by both the USAF and commercial air carriers to provide for interoperability and intermodality.

What has evolved is somewhat different. With the 463L precedent established, aircraft cargo systems, MHE and terminal facilities in the military air cargo system have been developed to handle the 108 inch by 88 inch pallet. On the commercial side, aircraft development has affected a standardization on 88 inch and 96 inch wide pallets. However, interoperability has been

retained with commercial air cargo aircraft. Most commercial air cargo aircraft can handle the 108 inch by 88 inch pallets; this capability apparently being retained with the incentive of CRAP airlift contracts. The military (MAC) aircraft cannot handle the commercial pallets. Details of the military and commercial pallets are covered in paragraphs 2.1.3.1.1 and 2.1.3.1.2.

2.1.3.1.1 Military Pallets. MIL-P-27443 covers three types of pallets, which were originally standardized for the 463L System:

<u>DESIGNATION</u>	<u>CAPACITY</u>	<u>DIMENSIONS</u>
BCU-6/E	10,000 lbs.	108" by 88" by 2-1/4"
BCU-12/E	5,000 lbs.	88" by 54" by 2-1/4"
BCU-10/C	5,000 lbs.	88" by 54" by 4-1/2"

Today, the entire 463L System revolves around the BCU-6/E and the roller conveyor systems used in cargo aircraft, aircraft loaders and terminal material handling equipment. The C-130, C-141B, C-5 and all CRAP aircraft have roller conveyor systems designed and installed to handle the BCU-6/E. The BCU-12/E is used to a limited extent on the DC-9, L-188 and L-100 LOGAIR aircraft, which can handle both the BCU-6/E and the BCU-12/E. The BCU-10/C is minimally used in the system.

The BCU-6/E has design features specifically tailored to provide capability with the 463L System. (See Figure 2-6.) It is important to note that all 463L roller conveyor systems (i.e., aircraft, MHE and terminals) were originally designed to accept the 108 inch side as a leading edge, i.e., pallet guides and restraints are designed for a 108 inch wide ULD. The pallet construction is of a balsa wood core with aluminum sheet outer surface (see Detail A, Figure 2-6). The entire periphery of the pallet consists of a rail structure provided with indents and a lip structure for interfacing with aircraft rail/ restraining systems (see Detail B, Figure 2-6).

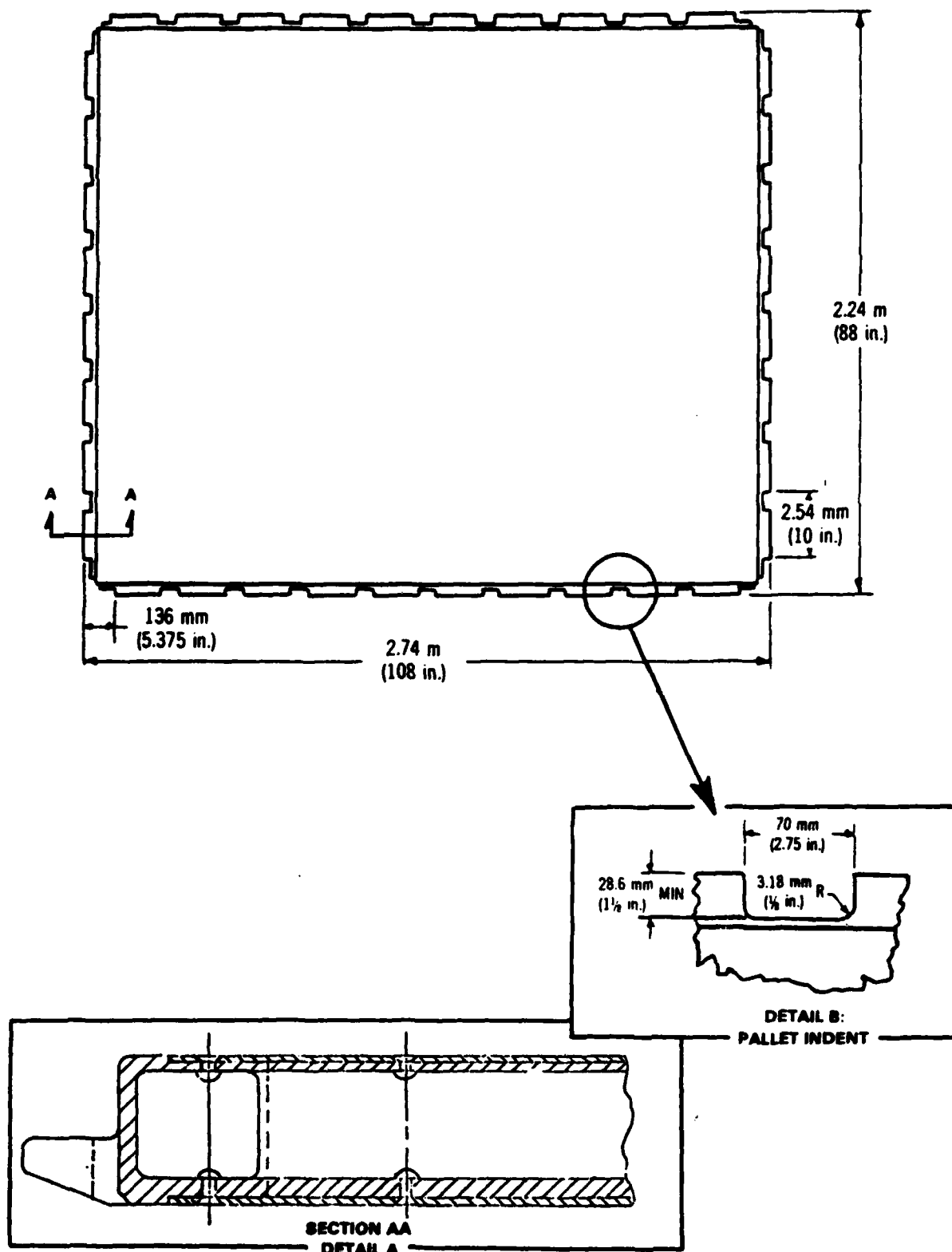


Figure 2-6 463L (HCU-6/E) Pallet

For full unitization of the HCU-6/E, the HCU-7/E and HCU-15/C cargo nets are used, resulting in a cargo ULD 108 inches by 88 inches by 96 inches. (See Figure 2-7.) Maximum capacity is 10,000 pounds. Average pallet loads for all logistics airlift is less than 5,000 pounds, with maximum loads on the order of 9,000 pounds (ammunition pallets). Pallets may be used "in-train" for cargo whose length exceeds the length of one pallet. A 2 inch spacer is required to couple pallets (up to a maximum of five). (See Figure 2-8.) The spacer ensures that married pallets mate with aircraft restraint locks.

The HCU-6/E is the ULD used most frequently in the military air cargo system. If cargo can be placed on this pallet, no additional effort is required to achieve air transport. Designers of air cargo MHE should bear in mind the key role of the HCU-6/E in the system and the impact of this role in the interrelationship and interface requirement between all system elements.

2.1.3.1.2 Commercial Pallets. Commercial airlines have standardized on two basic width pallets, 88 inches and 96 inches. Several options of the 88 inch and 96 inch base are contained in Figure 2-9. These standardized sizes followed aircraft development, as opposed to the military system, wherein aircraft were modified or developed to handle the standard 463L pallets. The 88 inch wide pallet resulted from narrow-bodied aircraft cargo compartment and cargo door sizes followed by wide-bodied aircraft lower deck dimensions. Widebodied freighters made possible the 96 inch wide pallet. Of the total worldwide population of commercial pallets, the 88 inch base pallet is by far the largest quantity used. This is apparently due to the larger population of narrow-bodied aircraft.

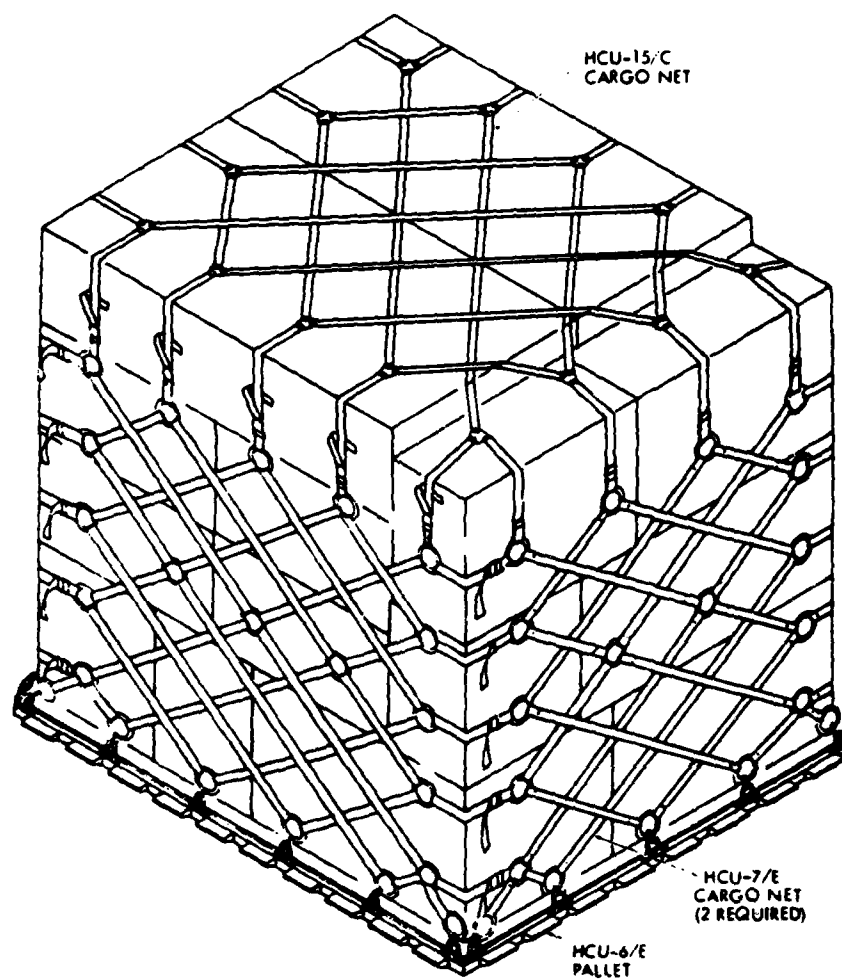


Figure 2-7 Unitized 463L Pallet

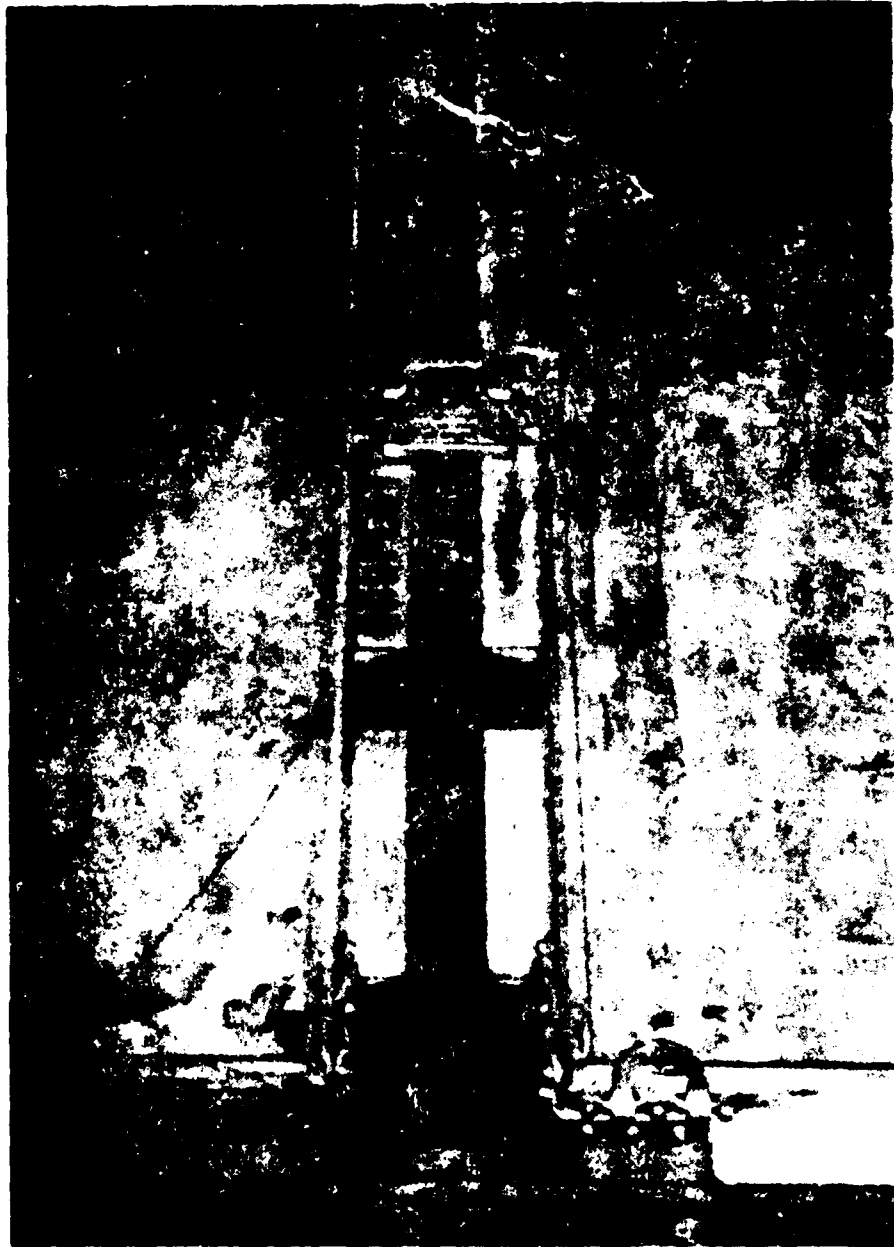
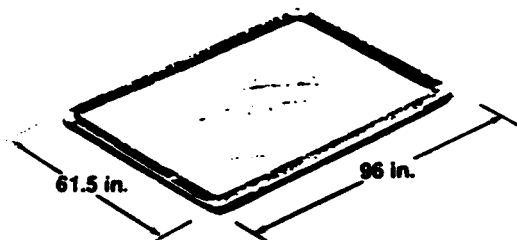
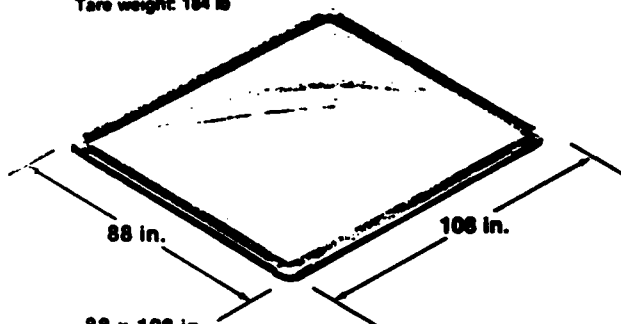


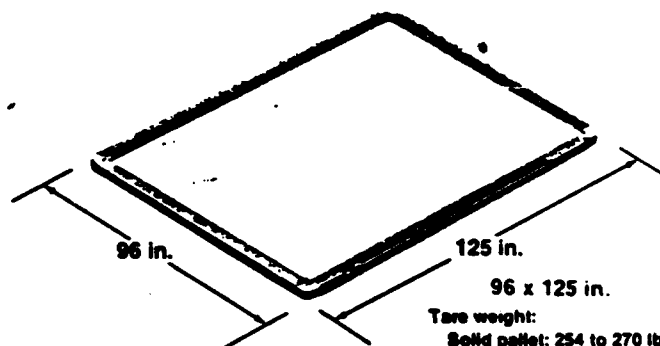
Figure 2-8 463L Pallet Spacer



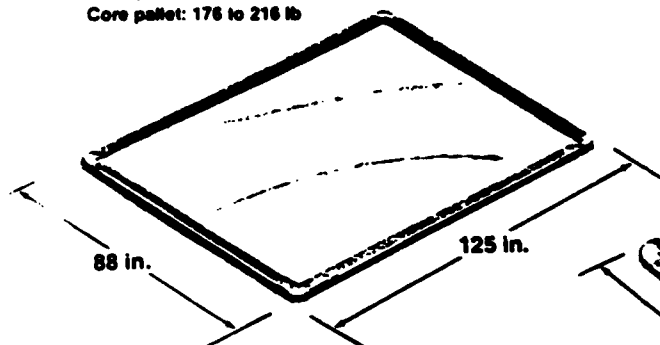
61.5 x 96 in.
Tare weight: 184 lb



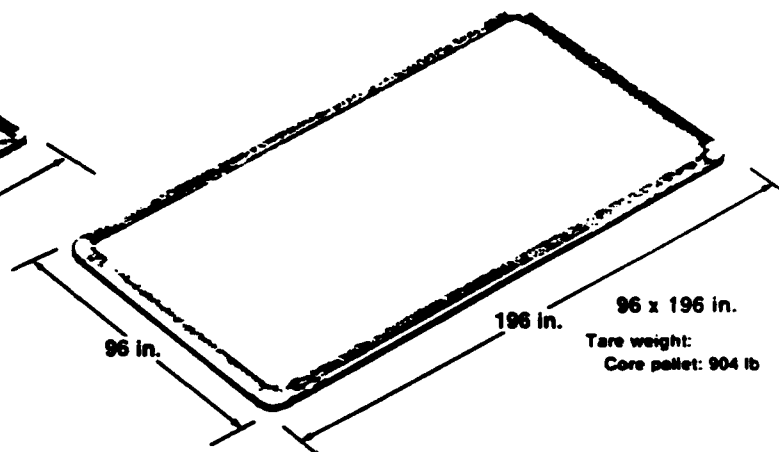
88 x 108 in.
Tare weight:
Solid pallet: 210 lb
Core pallet: 176 to 216 lb



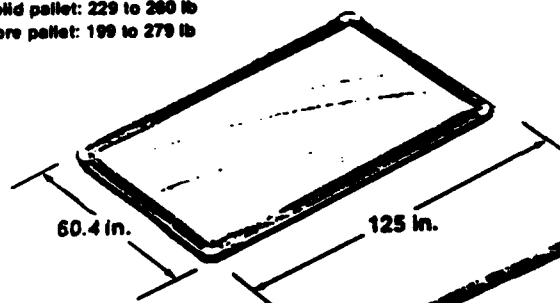
96 x 125 in.
Tare weight:
Solid pallet: 254 to 270 lb
Core pallet: 258 lb



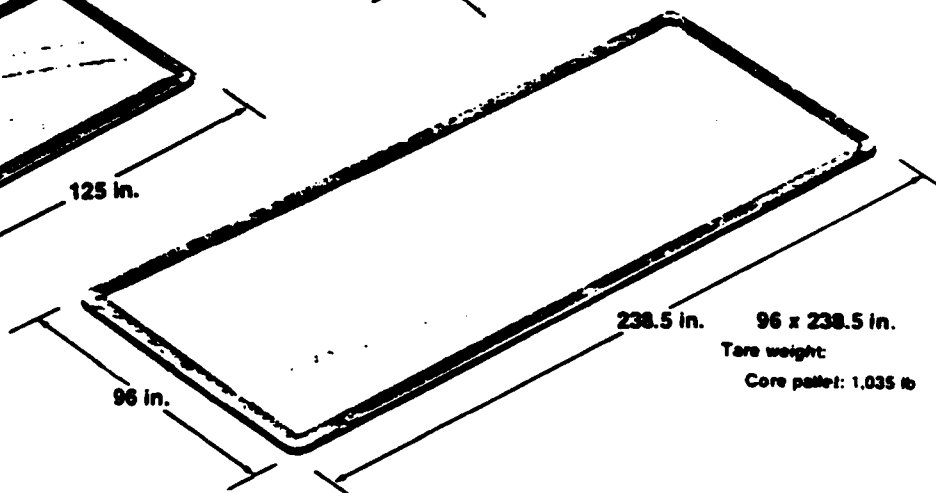
88 x 125 in.
Tare weight:
Solid pallet: 229 to 260 lb
Core pallet: 199 to 279 lb



96 x 196 in.
Tare weight:
Core pallet: 904 lb



60.40 x 125 in.
Tare weight:
Solid pallet: 187 lb
Core pallet: 200 lb



96 x 238.5 in.
Tare weight:
Core pallet: 1,035 lb

Figure 2-9 Commercial Pallets
2-28

Commercial pallets are not used in the 463L System. In those rare instances where cargo must be transhipped from commercial to 463L pallets, commercial pallets (with cargo) are secured on 463L pallets for air transit in the 463L System.

2.1.3.2 Platforms. An ancillary mission of USAF cargo aircraft is airdrop of equipment and supplies under combat conditions. This added mission for cargo aircraft has resulted in special design of the roller/rail conveyor systems. As a result, these systems are more rugged than those on commercial aircraft and result in higher load ratings.

Three platforms are currently available for use on board USAF aircraft. These platforms are used for both logistics and aerial delivery. In logistics applications, the components of these three platforms can be used for air transport of special equipment, providing a platform which is readily accommodated by the aircraft roller conveyor systems. These three platforms are the Type II Modular platform, the A/E29H-1 (Metric) platform and the Type V platform. They are designed primarily for heavy airdrop (both low and high velocity) and Low Altitude Parachute Extraction (LAPE). Other airdrop systems consists of Container Airdrop and the Container Delivery System.

2.1.3.2.1 Type II Modular Platform. The Type II platform (see Figure 2-10) was designed for use with the 463L System in the airdrop mode. As the name suggests, the platform is modular in design, allowing for varying lengths of 8-, 12-, 16-, 20-, and 24 feet. The platform is 108 inches wide. Side rail construction includes an indent/lip configuration similar to the 463L pallet,

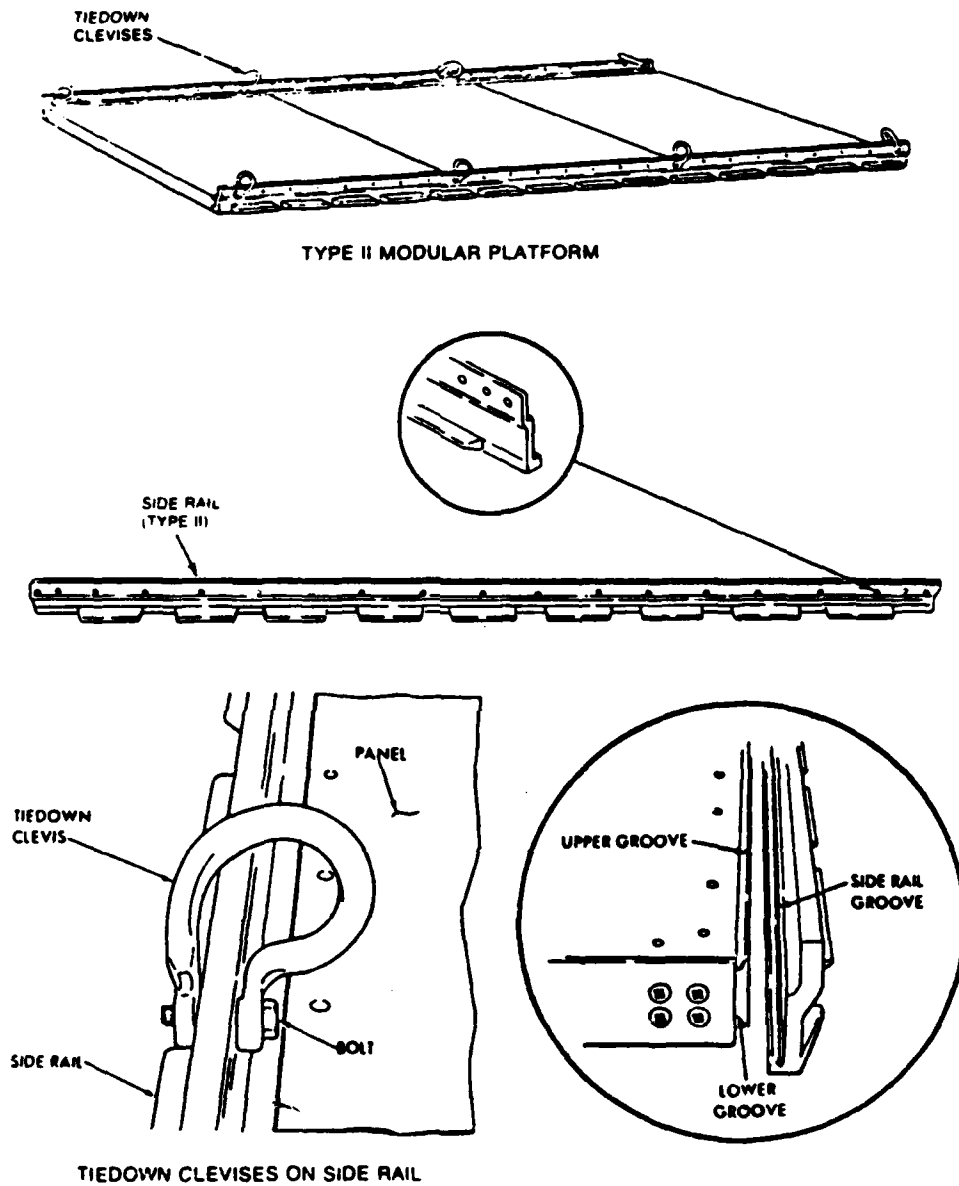


Figure 2-10 Type II Modular Platform

which provides compatibility with the restraint mechanism of aircraft roller conveyor systems. Maximum rigged weight of the 24 foot platform is 35,765 pounds.

2.1.3.2.2 A/E29H-1 (Metric) Platform. The Metric platform is also a modular-design, used primarily for performing LAPES airdrops with the C-130 (see Figure 2-11). This platform can also be used for standard heavy airdrop and logistics airlift; however, the four skids (required for LAPES airdrop) must be removed for the C-141 and C-5 because the roller systems on these aircraft do not provide sufficient clearance for the skids. Only the C-130 and 25K TAC loader roller systems can handle the Metric platform in the LAPES mode. Like the Type II platform, the Metric platform can be modularly assembled for 8-, 12-, 16-, 20-, and 24 foot lengths. Width of the platform is 108 inches, with side rails designed to be compatible with the 463L roller conveyor system. Maximum rigged weight is 37,175 pounds for the 24 foot platform.

2.1.3.2.3 The Type V (Joint Service) Platform. The Type V platform was designed to replace both the Type II Modular and the Metric LAPES platforms (see Figure 2-12). Development of this platform was directed at eliminating the structural inadequacy of the Type II aluminum-balsa sandwich construction and the skid set interference problem of the Metric platform, while still providing improved performance with higher rigged load capacity and platform length. It can be used for LAPES airdrop in both single platform and tandem platform modes, with the latest developed system being the Airdrop Controlled Exit System (ACES). (see Figure 2-13.)

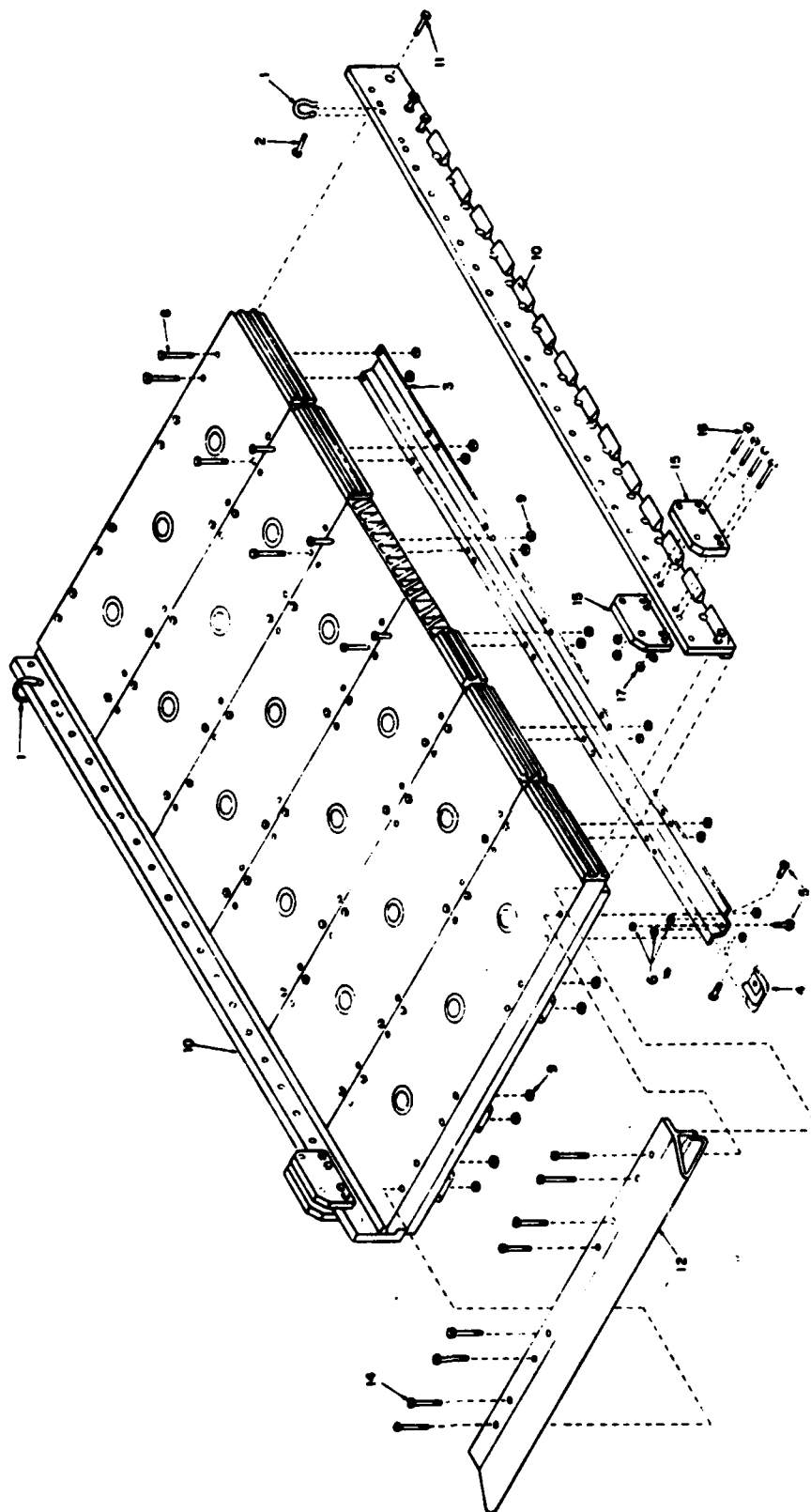


Figure 2-11 A/E 29 H-1 Metric Platform

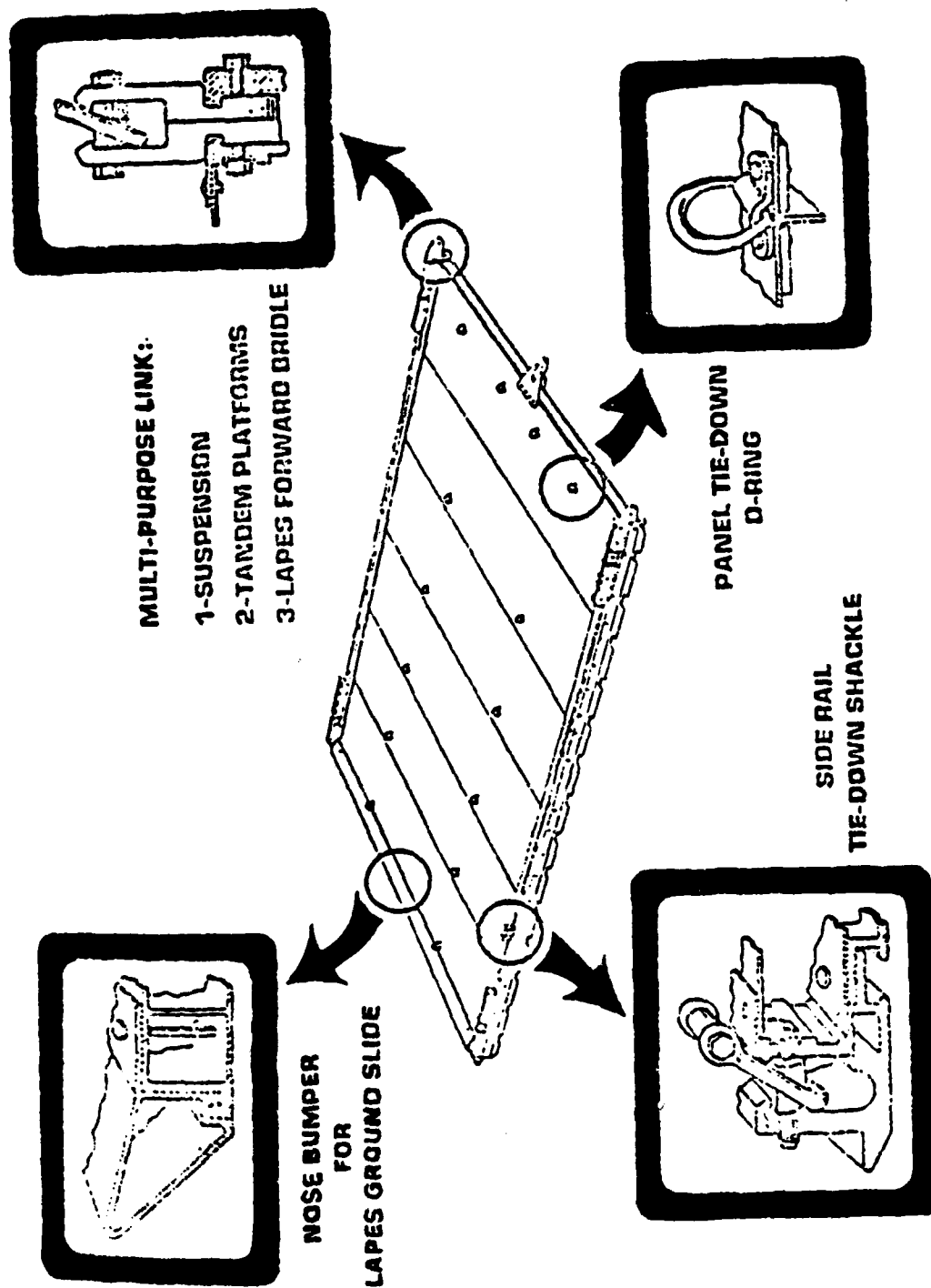


Figure 2-12 Type V (Joint Service) Platform

ACES

AIRDROP CONTROLLED EXIT SYSTEM

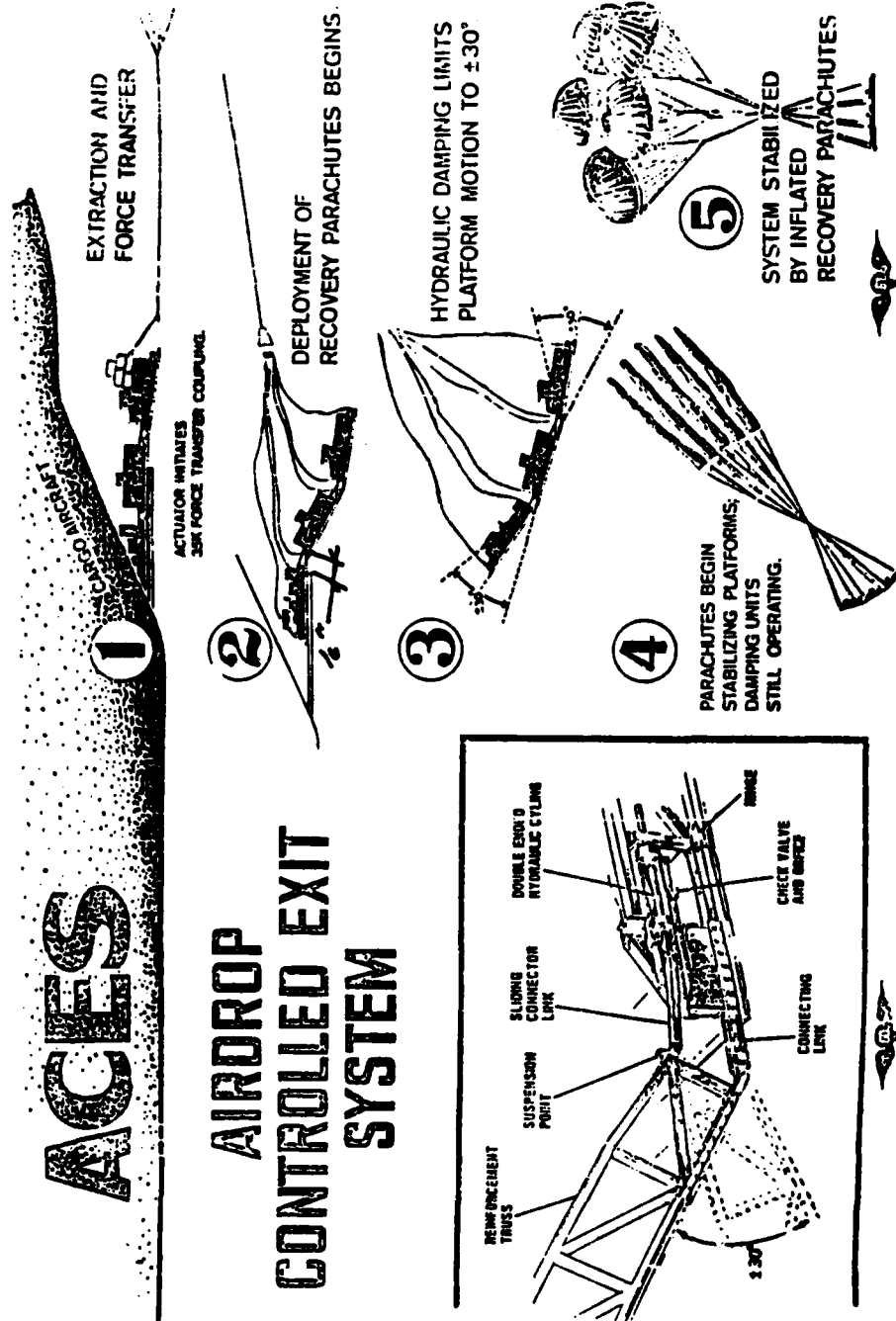


Figure 2-13 Airdrops Controlled Extraction System (ACES)

The Type V is a modular design with various platform lengths of 8, 12, 16, 20, 24, and 28 feet. Width of the platform is 108 inches, with side rail construction similar to the 463L pallet for compatibility with aircraft restraint mechanisms and roller conveyor systems. Maximum capacity is currently rated at 42,000 pounds for the 28 foot long platform. Continuing development will ultimately provide 60,000 pounds maximum rigged weight with a 32 foot platform. This capacity will be used both for ACES tandem platforms or single platform heavy airdrop.

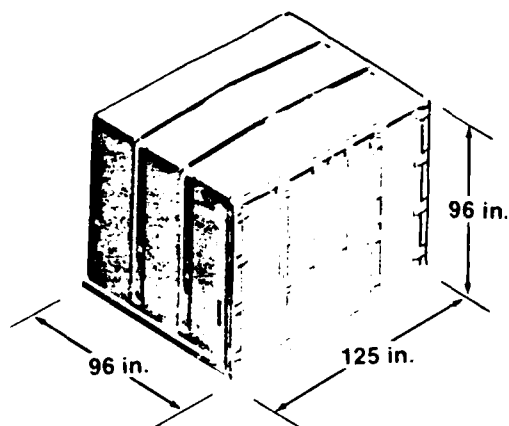
2.1.3.2.4 Container Airdrop. Both the C-130 and C-141B can be used for door bundle airdrop (A-21 Cargo Bag) and Container Delivery System (A-22 Cargo Bag). Maximum load capacity of these cargo bags are 500 pounds and 2,200 pounds respectively. The A-22 Cargo Bag is provided with a rigid base consisting of a 3/4 inch plywood skid, 48 inches by 53.5 inches. Ancillary restraint equipment must be used with these container systems since they do not interlock with the aircraft's rail/restraint system. Door bundles are skidded or pushed out of aircraft, while CDS containers are free rolled out of aircraft rear door ramps by gravity feed, achieved with a positive aircraft deck angle.

2.1.3.3 Containers/Tactical Shelters. Containerization of commercial air cargo has typically been an evolutionary process, largely predicated on cost effectiveness and the development of available airframes for air transport. The large number of types and sizes of air containers resulted from the progressive increase of available cabin space, starting with the lower deck of narrow-bodied jets, progressing to the main deck, followed by the lower-deck

and main-deck of wide-bodied aircraft. The favorable economics of using commercial aircraft for cargo transport, of course, has impacted the design of the aircraft. The latest influence on containerization of air cargo is the intermodal (surface) container and the financial success enjoyed by commercial surface cargo carriers. A sampling of containers (and netted pallets) is contained in Figure 2-14. A perusal of these containers illustrates the influence of, and extent to, which many of these containers were tailored for specific aircraft types, both in size (length and width) and in contoured shape. The result is a somewhat standardized width of 88 and 96 inches for main-deck containers and 60.4 and 88 inches for lower deck containers. The close parallel of this standardization with commercial pallets is not coincidental. Commercial containers were developed with the same design constraints as were pallets, namely, compatibility with commercial airframes and their roller conveyor systems. In fact, the non-structural containers use pallets as a base, with appropriate netting, to construct the container.

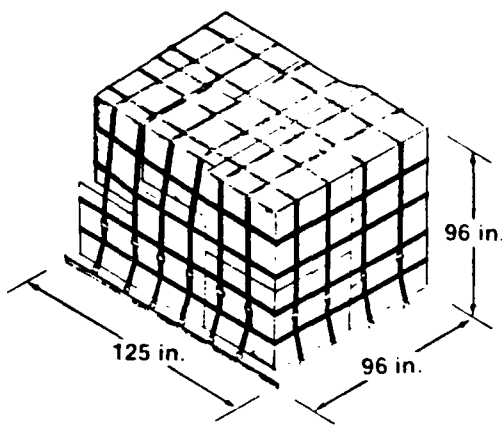
The 463L System is not designed for and therefore does not accommodate these containers. The commercial pallets, container widths and the side rail construction preclude their use in the military system. There are, however, circumstances wherein commercially configured containers must be airlifted by MAC aircraft. In these instances, the non-compliant-configured ULDs are treated as oversize cargo and restrained on 463L pallets, thus providing the necessary interface.

More significantly, the USAF has recognized the potential cost effective advantages of air intermodal containers, but more importantly, perceives that the bulk of commercial surface cargo transport is accomplished with International Standards Organization (ISO) surface containers. In times of contingency, the DoD will call on commercial surface carriers as well as



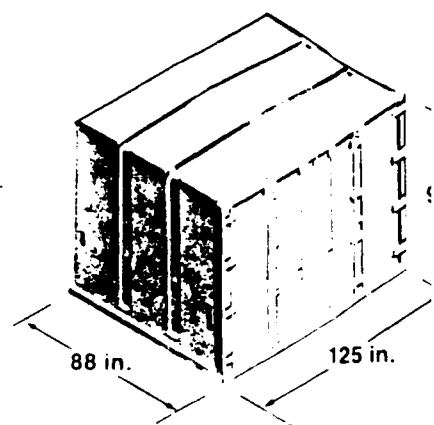
Type: M1 Structural Container

Internal volume: 572 to 634 cu ft
Tare weight: 1,024 to 1,150 lb
Weight limitations: 15,000 lb



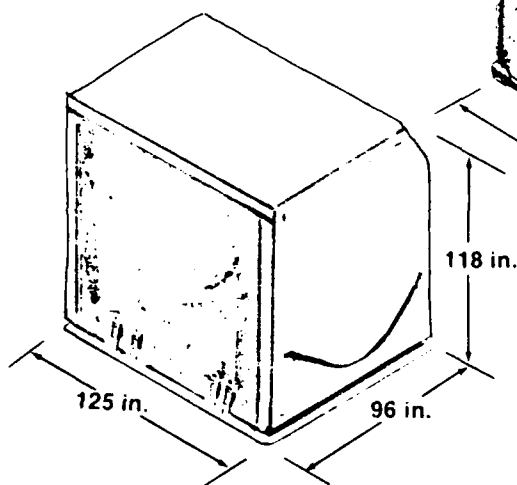
Type: M1 Netted Pallet

Internal volume: 630 cu ft
Tare weight pallet:
1. Solid aluminum sheet: 254 to 270 lb
2. Aluminum with balsa core: 258 lb
Tare weight, net: 47 lb
Weight limitations: 15,000 lb



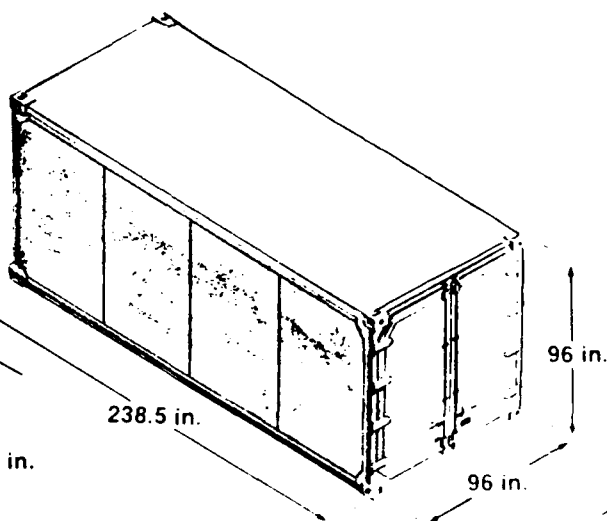
Type: M3 Structural Container

Internal volume: 560 cu ft
Tare weight: 925 lb
Weight limitations: 15,000 lb



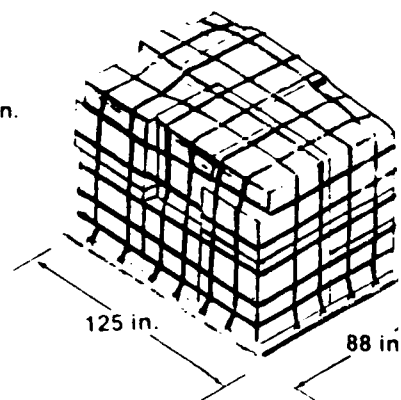
Type: M1H Structural Container

Internal volume: 760 to 773 cu ft
Tare weight: 705 lb
Weight limitations: 15,000 lb



Type: M2 Structural Container

(Without corner fittings)
Internal volume: 1,178 cu ft
Tare weight: 2,090 lb
Weight limitations: 25,000 lb

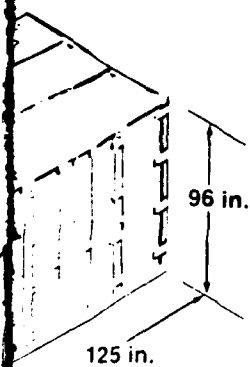


Type: M4 Netted Pallet

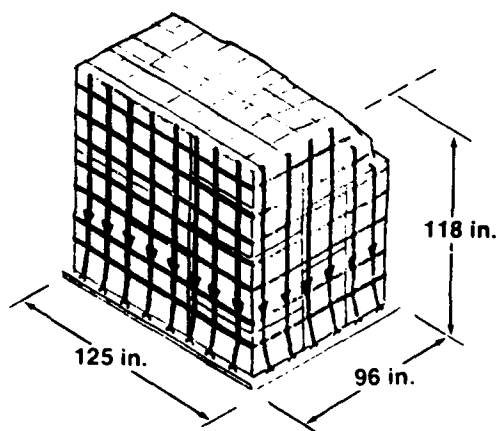
Internal volume: 490 cu ft
Tare weight, pallet:
1. Solid aluminum sheet: 229 to 260 lb
2. Aluminum with balsa core: 199 to 229 lb
Tare weight, net: 35 lb
Weight limitations: 10,200 to 13,300 lb

Type: M2 Structural Container

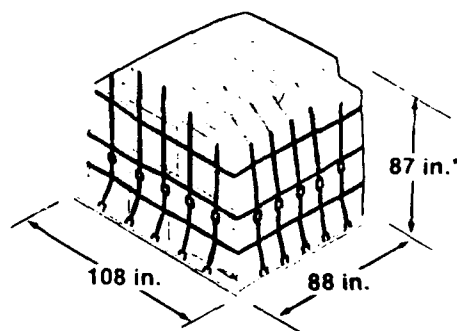
(With corner fittings)
Internal volume: 1,165 cu ft
Tare weight: 2,115 lb
Weight limitations: 25,000 lb



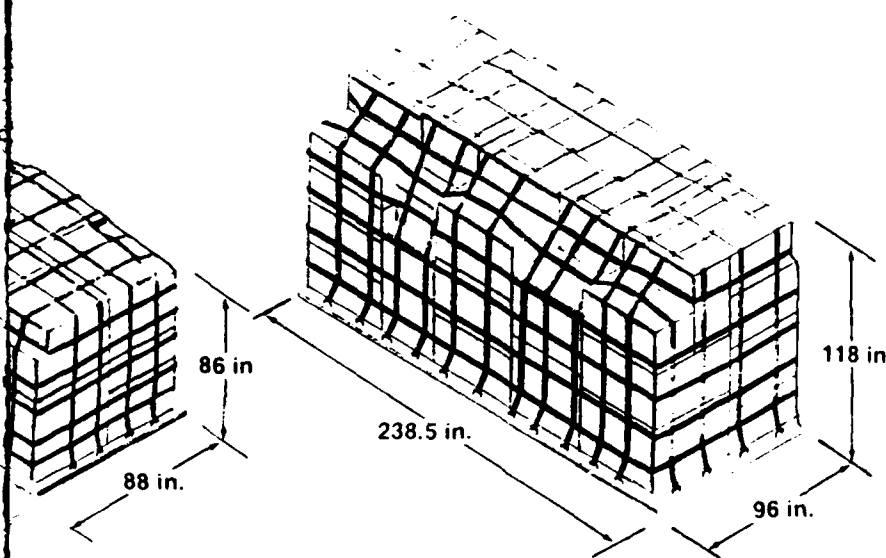
Structural Container
Internal volume: 311 to 380 cu ft
Tare weight, net: 46 lb
Weight limitations: 15,000 lb



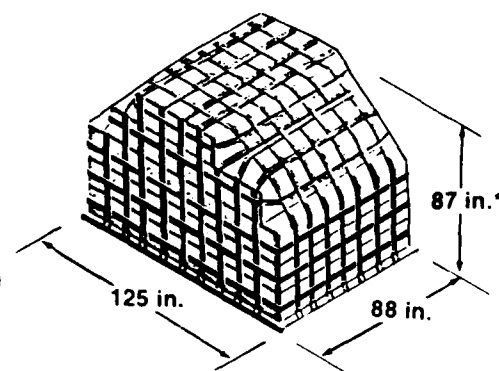
Type: M5 Netted Pallet
Internal volume: 745 cu ft
Tare weight, pallet: 254 to 270 lb (no support structure)
Tare weight, net: 46 lb
Weight limitations: 15,000 lb



Type: A Netted Pallet
Internal volume: 311 to 380 cu ft
Tare weight, pallet:
1. Solid aluminum sheet: 210 lb
2. Aluminum with balsa core: 176 to 216 lb
Tare weight, net: 30 to 75 lb
Weight limitations: 8,000 to 10,000 lb

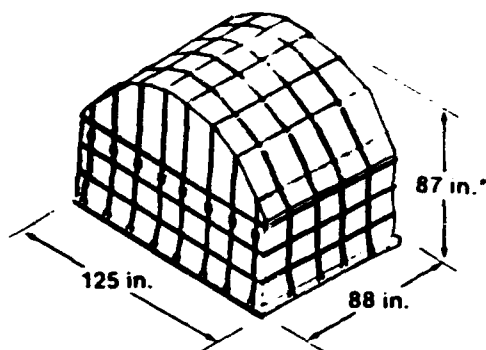


Type: M6 Netted Pallet
Internal volume: 1,483 cu ft
Tare weight, pallet:
1. Solid aluminum sheet: 229 to 260 lb
2. Aluminum with balsa core: 199 to 279 lb
Tare weight, net: 33 to 80 lb
Weight limitations: 10,000 to 13,300 lb



Type: A1, A2, or A3 Netted Pallet
Internal volume: 379 to 505 cu ft
Tare weight, pallet:
1. Solid aluminum sheet: 229 to 260 lb
2. Aluminum with balsa core: 199 to 279 lb
Tare weight, net: 33 to 80 lb
Weight limitations: 10,000 to 13,300 lb

Figure 2-14 Commercial Containers (Sheet 1 of 2)



Type: A1, A2, or A3 Container

Internal volume:

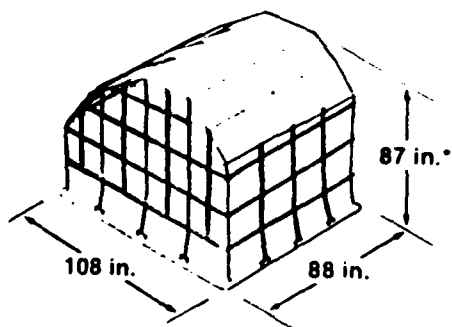
1. Structural design: 390 to 458 cu ft
2. Nonstructural design: 371 to 460 cu ft

Tare weight:

1. Structural design: 760 to 810 lb
2. Nonstructural design: 452 to 692 lb

Weight limitations:

1. Structural design: 10,000 to 13,300 lb
2. Nonstructural design: 8,000 to 13,300 lb



Type: A4 Container

Internal volume:

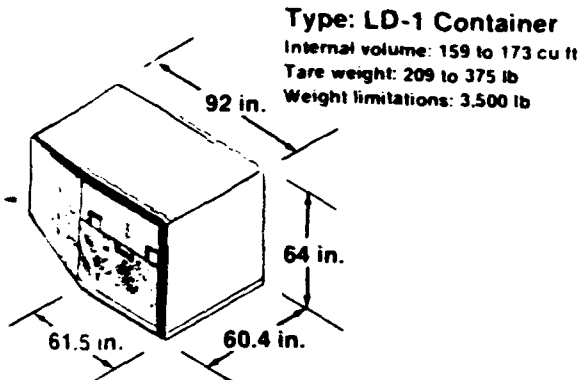
1. Structural design: 345 to 380 cu ft
2. Nonstructural design: 303 to 364 cu ft

Tare weight:

1. Structural design: 470 to 570 lb
2. Nonstructural design: 397 to 551 lb

Weight limitations:

1. Structural design: 8,000 lb
2. Nonstructural design: 8,000 to 10,000 lb

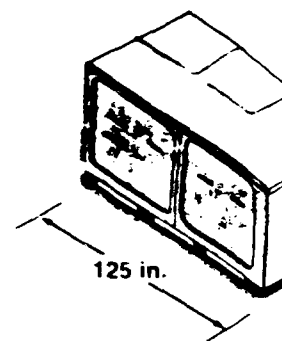


Type: LD-1 Container

Internal volume: 159 to 173 cu ft

Tare weight: 209 to 375 lb

Weight limitations: 3,500 lb

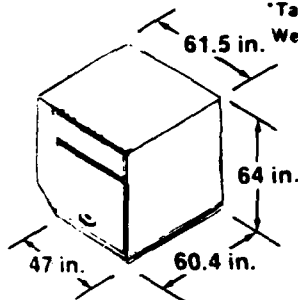


Type: LD-2 Container

Internal volume: 120 cu ft

Tare weight: 152 to 165 lb

Weight limitations: 2,700 lb



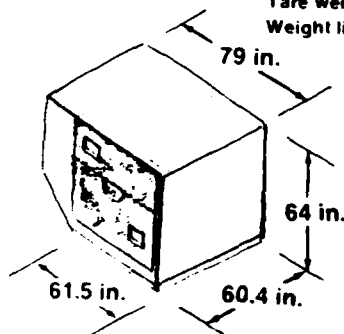
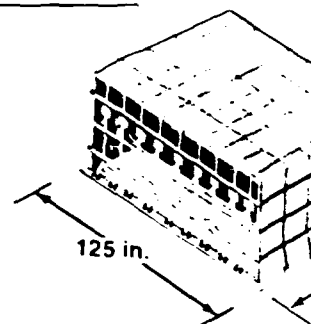
Type: LD-3 Container

Internal volume: 145 to 158 cu ft

Tare weight: 150 to 370 lb

Weight limitations: 3,500 lb

Rectangular



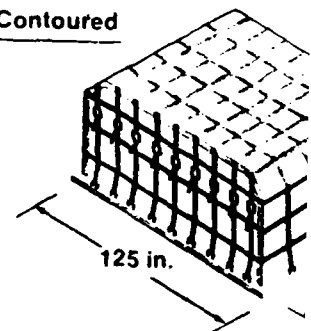
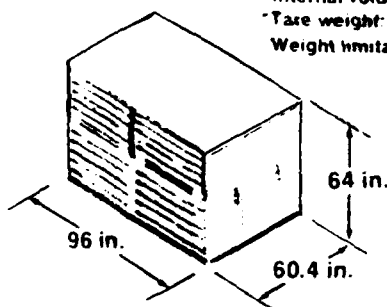
Type: LD-4 Structural Container

Internal volume: 202 cu ft

Tare weight: 240 lb

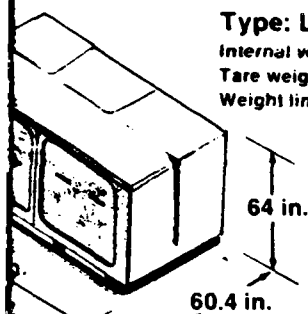
Weight limitations: 5,400 lb

Contoured



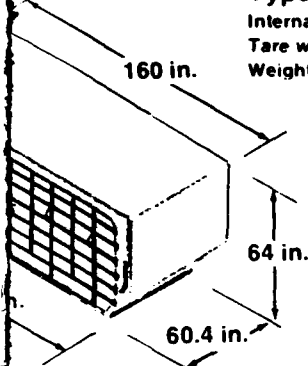
Type: LD-5 Structural Container

Internal volume: 243 cu ft
Tare weight: 430 to 600 lb
Weight limitations: 6,500 lb



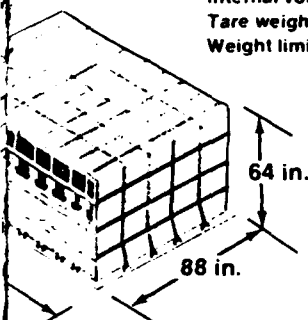
Type: LD-6 Structural Container

Internal volume: 316 cu ft
Tare weight: 385 to 485 lb
Weight limitations: 7,000 lb

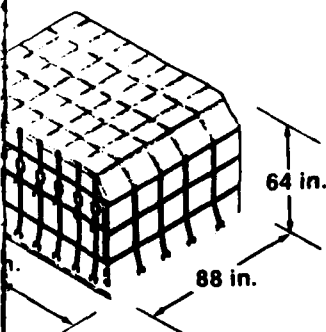
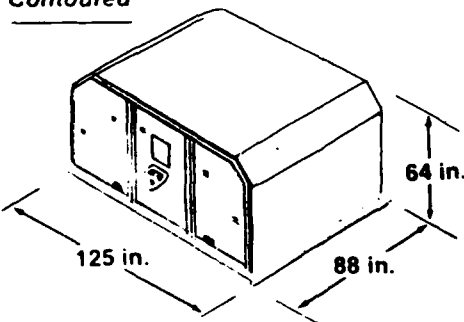


Type: LD-7 Nonstructural Container

Internal volume: 329 to 392 cu ft
Tare weight: 475 to 665 lb
Weight limitations: 10,200 lb

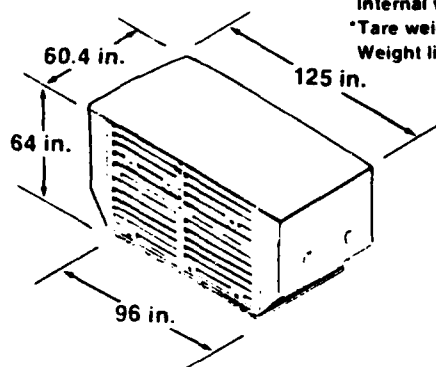


Contoured

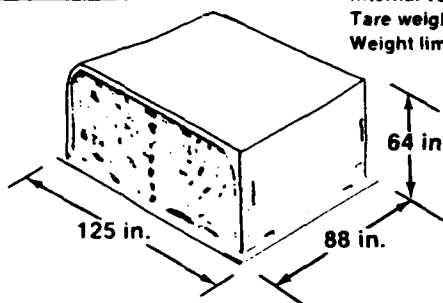


Type: LD-8 Structural Container

Internal volume: 245 cu ft
Tare weight: 265 lb
Weight limitations: 5,400 lb

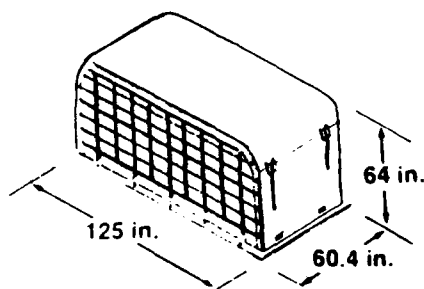


***Rectangular**



Type: LD-9 Structural Container

Internal volume: 329 to 381 cu ft
Tare weight: 485 to 720 lb
Weight limitations: 10,200 lb



Type: LD-10 Structural Container

Internal volume: 242 to 246 cu ft
Tare weight: 375 to 650 lb
Weight limitations: 5,680 to 7,000 lb

Type: LD-11 Structural Container

Internal volume: 246 to 254 cu ft
Tare weight: 410 to 630 lb
Weight limitations: 5,680 to 7,000 lb

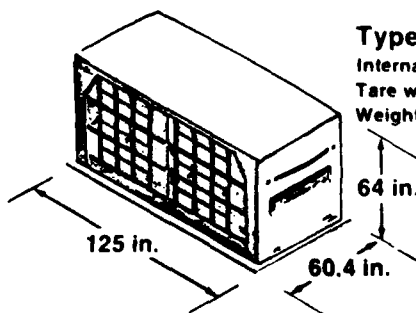


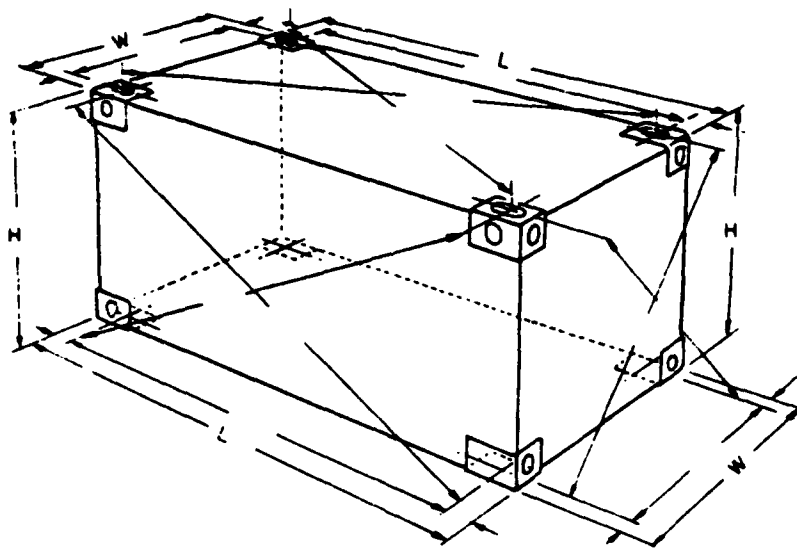
Figure 2-14 Commercial Containers (Sheet 2 of 2)

airlines to handle the overload. The demand for airlift will increase proportionately, with the possible introduction of surface containers into the airlift system. CRAF aircraft can handle the air intermodal containers, but the base structure of surface containers cannot interface with the roller conveyor systems of neither the commercial aircraft nor the military aircraft. To obviate this deficiency, the USAF is developing a container/tactical shelter adapter to serve as a base for both the military 108 inch and the commercial 96 inch systems. Airlift of ISO containers is not exactly an unanticipated requirement in that ISO containers, MILVANS and ISO-configured shelters are currently airlifted in the low-demand, peace-time environment.

Tactical shelters are standardized to a base-line family group of shelters as authorized by DoD Instruction 4500.37. The majority of these tactical shelters are designed with corner fittings and design structure similar to those of the ISO surface containers. While having the same facility of handling by container MHE, they have the same disadvantage of a skeletal floor structure, which cannot be accommodated by roller conveyor systems. A 463L pallet base must be provided for air transport.

2.1.3.3.1 ISO Containers. There are two types of ISO Containers, the surface intermodal container and the air/surface intermodal container. Specifications for these containers are contained in ISO 668 and ISO 8323, respectively.

Both types are identical in external dimensions and end corner fittings (ISO 1161), see Figure 2-15. These characteristics retain the commonality required for intermodality between air and surface transport. The two types are dissimilar in design structure and material, particularly in the floor



NOMINAL LENGTH FEET	LENGTH OVERALL FT. IN.	WIDTH OVERALL FT. IN.	HEIGHT OVERALL FT. IN.	MAX. GROSS WEIGHT	
				AIR/SURFACE (LBS)	SURFACE (LBS)
40	40'0"	8'0"	8'0"	45,000	67,200
30	29'11¼"		OR	35,000	56,000
20	19'10½"		8'6½"	25,000	44,800
10	9'9¼"			12,500	22,400

Figure 2-15 ISO Container Dimentions & Weights

structure (see Figure 2-16). The air/surface container has a flat bottom surface designed for support and movement on roller conveyor systems. Lower tare weights are achieved with lightweight and -gage material and structure. The maximum gross weight of air/surface and surface ISO containers are also listed in Figure 2-15.

MAC has tested and evaluated the feasibility of moving 20 foot ISO air/surface containers in the inter-theatre (channel) airlift system (REF: AFCSG Minutes, August, 1985, Appendix E). Results of the tests indicated that containers are more efficient than pallets in both cube (volume) and weight use. With these substantiating test results, the DoD has approved procurement of 50 air/surface containers for an established U.S. Army requirement of 45 container movements per month to support its air lines of communication between the U.S. and Europe.

MILVANS are the only containers of substantial quantity (6000+) integrated into the military logistics network. (The MILVAN configuration is essentially that of the 20 foot ISO container). MILVANS are primarily used for surface transport of ammunition and small size cargo. Over 4,000 of the MILVANS are equipped with internal restraints for ammunition, indicating the preferred usage for the MILVAN. There are priority situations when MILVANS (and other ISO container equivalents) must be air transported, in spite of the weight penalty of the higher tare weight.

USAF studies have shown that the quantity of MILVANS currently on-hand is insufficient for wartime demands (REF: AFCSG Minutes, August, 1985, Appendix E). To cover the shortfall, these studies indicate that 20 foot ISO surface containers will probably be used and it is reasonable to conclude that there will be a proportionate increase in airlift of surface containers.

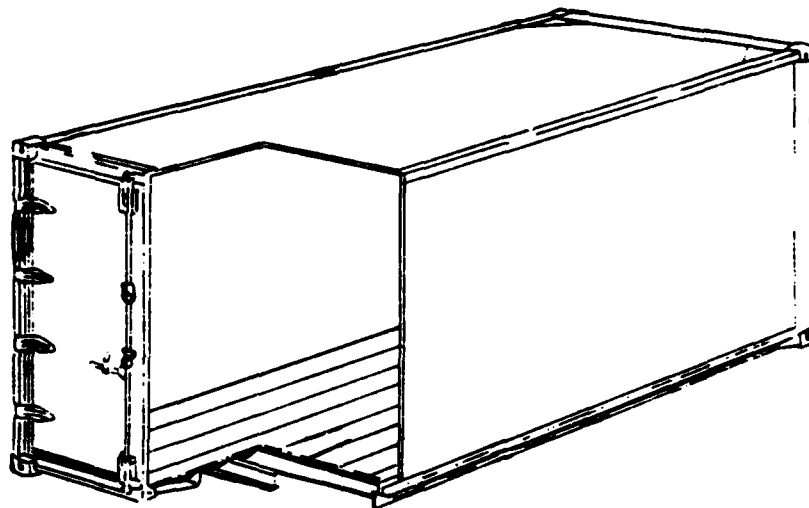
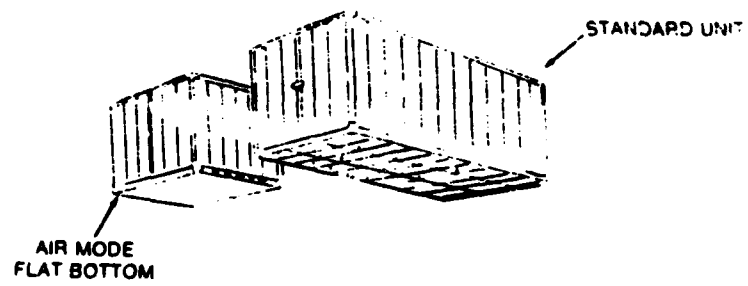


Figure 2-16 ISO Surface & Air/Surface Containers

These examples of airlift ISO containers, i.e., air/surface containers for U.S. Army ALOC requirements and priority airlifts of MILVANS (and ISO surface containers), are a manifestation of an evolving and increasing USAF Containerization System. Through the coordinating efforts and guidance of the Air Force Containerization System Development Group (AFCSDG), the methods and procedures for use and movement of ISO containers and tactical shelters will be developed. This is AFCSDG's charter, which is evidenced in its objectives, namely:

1. Make the Air Force logistics system capable of shipping, handling and receiving large volumes of containers and tactical shelters under contingency conditions.
2. Make CONUS and oversea air terminals and Air Force consignees capable of supporting intermodal container movements in a pure military environment.

A pending and significant input to the development of the containerization system will be the results of the "Container Movement Requirements by Air in the year 2000" project. The purpose of this DOT Transportation Systems Center study is to estimate air movement requirements for ISO container equivalents (containers and tactical shelters) through the year 2000. Preliminary projections of the study indicate that DoD requirements will indicate highest usage of the 20 foot ISO air/surface container.

The impact that the ISO container/shelter has on the 463L System goes beyond the realized increased efficiency in cube and weight utilization. Interoperability between the 463L military system and commercial air cargo systems was virtually lost with development of commercial aircraft and the resulting main deck ULDs developed for those aircraft. Having standardized on the 463L System, the USAF resisted any change to retain interoperability with commercial systems, primarily because of the cost impact of changing the system.

The leverage of CRAF contract airlift has served to ensure that commercial airlines retain interoperability with the 463L System. The cost to the USAF of retaining the 463L System is that required for the CRAF Enhancement Program. Apparently, this cost is substantially less than would be required for conversion of the 463L System.

Conversion to containerization will cost more to realize higher cost effective cargo handling capability, but the added incentive is the addition of intermodality. By introducing an interfacing adapter to handle ISO-configured ULDs and the necessary container handling equipment (CHE) into the 463L System this modest investment supplements the military air cargo system with the high volume and high density capability of both air and surface commercial cargo container systems.

2.1.3.3.2 Lower Deck Containers. Only the CRAF wide-bodied aircraft carry containers in their lower lobes. CRAF contracts do not require the use of baggage containers; however, should the need arise, carriers will be required to furnish appropriate containers. All the wide-bodied aircraft can carry LD containers with the 125 inch by 60.4 inch base (or half-containers with the 61.5 inch by 60.4 inch base). These usually include the LD-1, LD-3, and LD-6.

Preferred methods of lower lobe loading are bulk loading of baggage/cargo by hand or by using tri-wall containers.

Only the B747 can carry the 463L pallet in the lower lobe.

Tri-wall containers and 463L pallets are loaded/unloaded using a forklift or K-loader. Bulk loading by hand can be accomplished from a flat bed truck.

2.1.3.3.3 Tactical Shelters. The Joint Committee on Tactical Shelters (JOCOTAS) has established a Standard Family of Tactical Shelters. The current family of tactical shelters includes 13 types. These were established from a current list of 100 different configurations. Of the 13 types of the basic family, 10 are ISO-configured, See Figure 2-17. As new requirements occur, additional shelters will be added to the family. To the extent that is practical, additional shelter types will conform to applicable ANSI/ISO Container Standards. Technical parameters for development of new DoD shelters are covered in MIL-STD-907B. Maximum Gross Weight is 20,000 pounds (the 8X8X20 Navy Mobile Facility System).

Projected inventories for tactical shelters for FY'90 is in excess of 30,000 units, with Air Force estimates that half the shelter inventory will require airlift each month in wartime conditions.

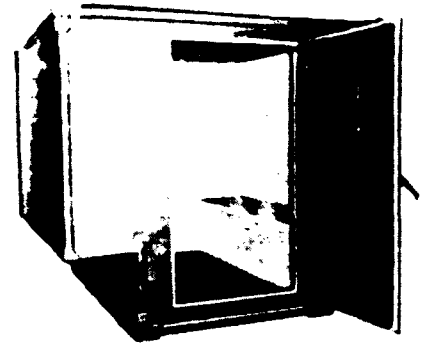
2.1.3.3.4 Container/Shelter Adapter System. The Container/Shelter Adapter System will provide means for rapid loading/unloading and securing ISO-configured ULDs on the C-130, C-141, C-5 and C-17 military aircraft and the B747. The ISO-configured ULDs include 20 foot Surface Containers (ISO 668), Air/Surface Containers (ISO 8323), Tactical Shelters (MIL-STD-907B), 3 ISO Tricons (8'X8'X6-2/3'), 4 ISO Quadcons (8'X8'X5') or 2 ISO Halfcons (8'X8'X10').

The purpose of the adapter system will be to provide an interfacing base for both the 463L System and 96 inch commercial roller conveyor system by:

1. Providing a flat supporting surface for ISO containers and shelters.
2. Providing a side rail lip interface for positive locking into the rail/restraint systems of both the 463L (100 inch) and commercial (96 inch) aircraft.
3. Providing an ISO locking device for securing ULDs by means of their ISO corner fittings.

6x6½x7

- 6'Hx6½'Wx7'L EXTERIOR DIMENSIONS
- 64"Hx75"W AT TOP, 44"W AT FLOOR
x78"L (46"H SIDE WALL)
- INTERIOR DIMENSIONS
- 770 LB TARE WEIGHT
- 1900 LB PAYLOAD
- 2670 LB GROSS WEIGHT
- EMI SHIELDED WHEN REQUIRED
- SPECIFICATION MIL-S-55541



S 250()/G

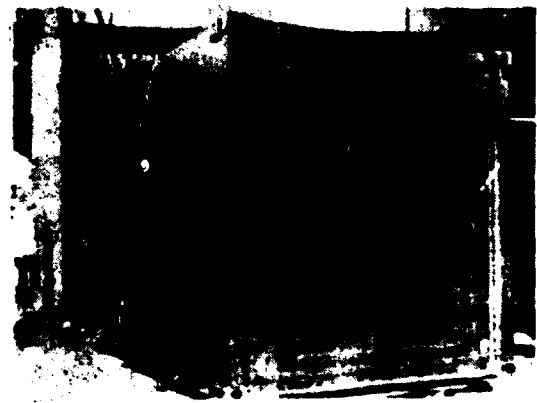
7½x7½x12



S 280 C G

- 7½'Hx7½'Wx12'L EXTERIOR DIMENSIONS
- 6'5"Hx6'10"Wx11'6"L INTERIOR DIM.
- 1400 LB TARE WEIGHT
- 5000 LB PAYLOAD
- 6400 LB GROSS WEIGHT
- EMI SHIELDED WHEN REQUIRED
- SPECIFICATION MIL-S-55286

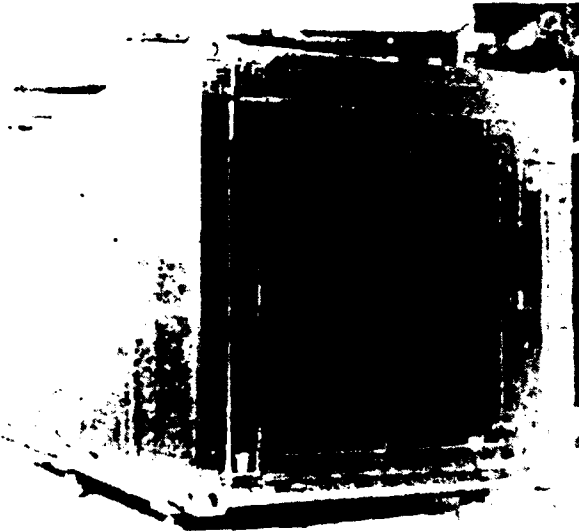
8x8x10 ISO



- 8'Hx8'Wx9'11"L EXTERIOR
- 7'2"Hx7'6"Wx9'L INTERIOR
- 2670 LB TARE WEIGHT
- 3500 LB PAYLOAD
- 6170 LB GROSS WEIGHT

EMI SHIELDED

8x8x20 ISO

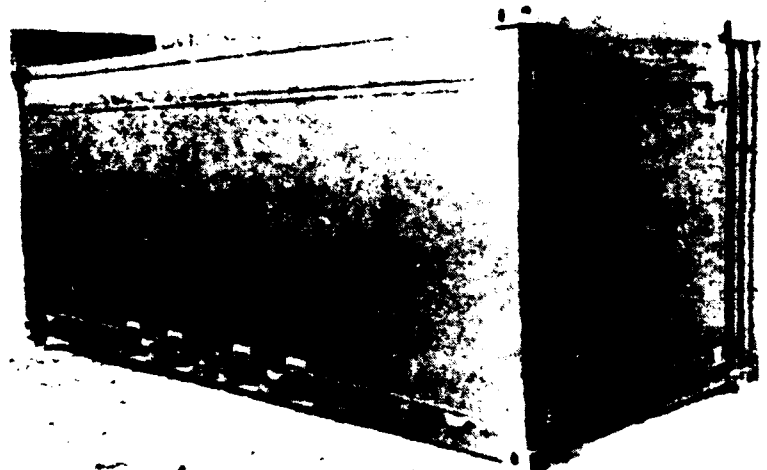


- 8'Hx8'Wx19'10½"L EXTERIOR
- 7'2"Hx7'6"Wx19'1"L INTERIOR
- 4180 LB TARE WEIGHT
- 7000 LB PAYLOAD
- 11,180 LB GROSS WEIGHT
- WALLS NOT REMOVABLE

EMI SHIELDED

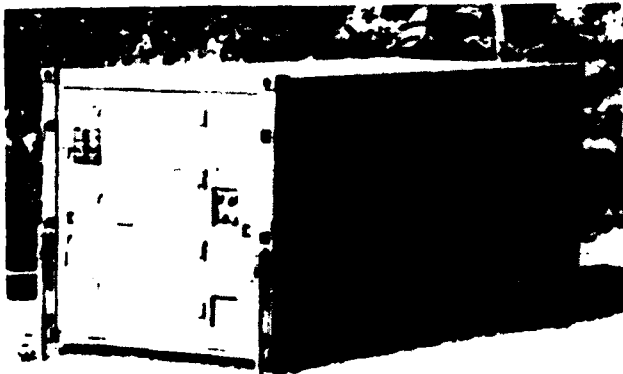
8x8x20 ISO

- 8'Hx8'Wx19'10½"L EXTERIOR
- 7'1"Hx7'5"Wx19'L INTERIOR
- 6'2"H, FLOOR TO BEAM LIP
- 3900 LB TARE WEIGHT
- 7000 LB PAYLOAD
- 10,900 LB GROSS WEIGHT
- SIDES REMOVABLE FOR COMPLEXING



GENERAL PURPOSE

8x8x20 ISO

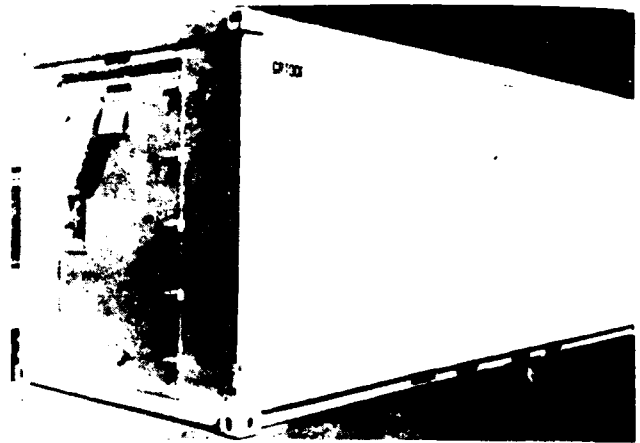


GENERAL PURPOSE

- 8'Hx8'Wx19'10½"L EXTERIOR DIMENSIONS
- 7'1"Hx7'7"Wx19'1"L INTERIOR DIMENSIONS
- 3900 LB TARE WEIGHT
- 10,000 LB PAYLOAD
- 13,900 LB GROSS WEIGHT

Figure 2-17 Tactical Shelters (Sheet 1 of 3)

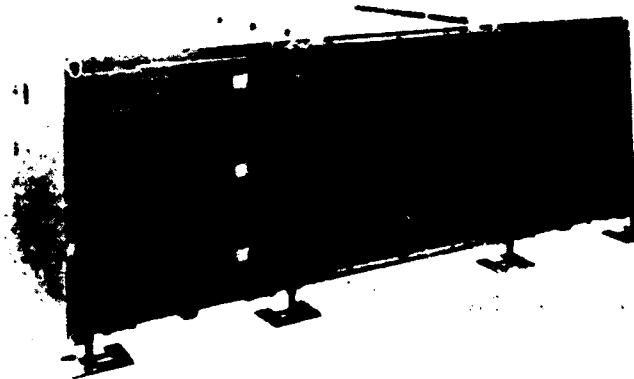
8x8x20 ISO



BASIC MOBILE FACILITY

- 8'Hx8'Wx19'10 1/2" L EXTERIOR DIM.
- 7'1"Hx7'6"Wx19'4" L INTERIOR DIM.
- 4900 LB TARE WEIGHT
- 15,100 LB PAYLOAD
- 20,000 LB GROSS WEIGHT
- SPECIFICATION MIL-M-81957A(AS)

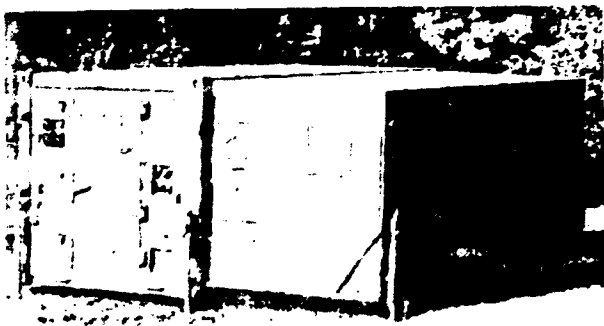
7 1/2 x 7 1/2 x 12



S 530 A/G EXPANDED

- 7'6"Hx7'3"Wx12'2"L EXTERIOR DIMENSIONS
- 6'9"Hx6'7"Wx11'5"L INT. NON-EXPANDED
- 6'9"Hx19'9"Wx11'5"L INT. EXPANDED
- 2 SHELTERS ARE JOINED FOR EXPANDED MODE
- 45 MINUTES, 6 MEN ERECTION TIME
- 2000 LB TARE WEIGHT
- 4500 LB PAYLOAD
- 6500 LB GROSS WEIGHT
- EMI WHEN REQUIRED

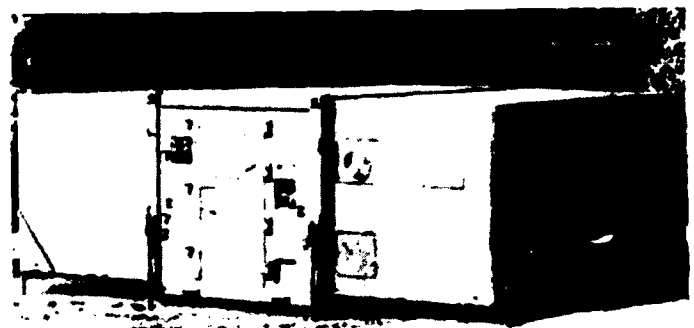
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ONE SIDE EXPANDABLE

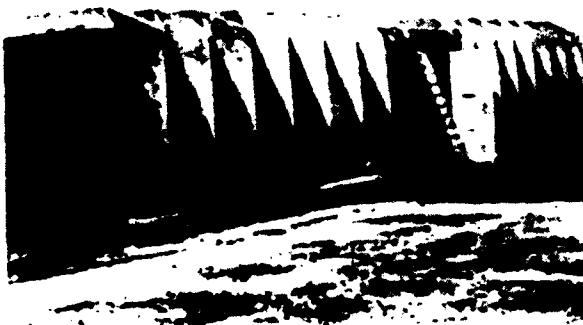
- 8'Hx8'Wx19'10½" L EXTERIOR DIMENSION
- 7'1" H x 6'5" W x 19'1" L INTERIOR NON-EXPANDED
- 7'1" H x 21'6" W x 18'4" L INTERIOR EXPANDED
- 6900 LB TARE WEIGHT
- 8100 LB PAYLOAD
- 15,000 LB GROSS WEIGHT
- 45 MINUTES, 4 MEN ERECTION TIME

8x8x20 ISO



TWO SIDES EXPANDABLE

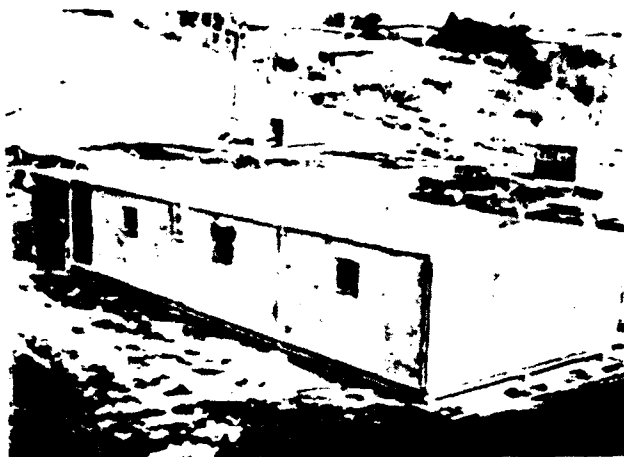
- 8'Hx8'Wx19'10½" L EXTERIOR DIMENSION
- 7'1" H x 49' W x 19' L INTERIOR EXPANDED
- 8000 LB TARE WEIGHT
- 4 HOURS, 4 MEN ERECTION TIME
- ACCORDION STYLE SIDES AND ROOF SHIPPED IN CONTAINER MODE
- 7000 LB PAYLOAD



50 FT EXPANDABLE (7 FOR 1)

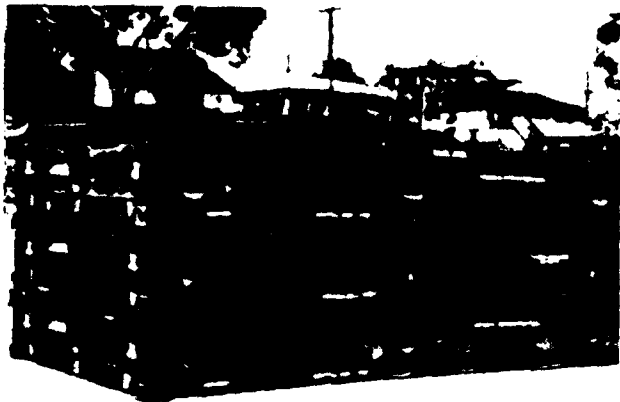
Figure 2-17 Tactical Shelters (Sheet 2 of 3)

8x8x20 ISO



EXTENDIBLE BUILDING

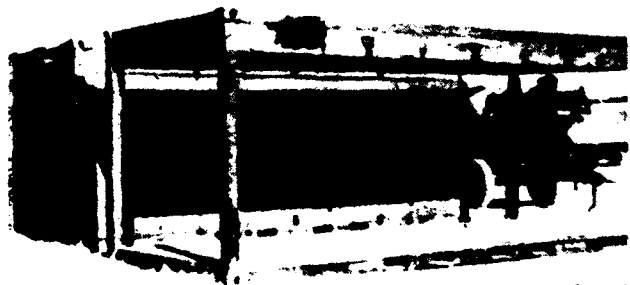
- 8'Hx8'Wx19'10 1/2" L EXTERIOR
- 8'Hx50'Wx19'11" L EXT. EXPANDED
- PANELS SHIPPED IN CONTAINER MODE
- 11,500 LB TARE WEIGHT
- 6.5 HOURS, 4 MEN ERECTION TIME



STORED

- 19'Hx8'Wx19'11" L KNOCKED DOWN
- 4 SHELTERS CAN BE TRANSPORTED IN 8x8x20 ISO MODE
- 20 MEN, 20 MIN. ERECTION TIME

8x8x20 ISO



ERECTED

- 7'11"Hx7'5"Wx19'L INTERIOR DIM.
- 6'2" H FLOOR TO BEAM
- 3650 LB TARE WEIGHT
- 45 LB/SQ. FT. FLOOR LOAD

Figure 2-17 Tactical Shelters (Sheet 3 of 3)

Rated capacity of the adapter system is for 20 foot ISO equivalents with a maximum gross weight of 44,800 pounds. Technical requirements for the container/shelter adapter system are contained in Critical Item Development Specification No. TSDO-C1-100.

2.1.3.4 Rolling Stock. The C-130, C-141B and C-5 aircraft are equipped (C-17 will be) with loading ramps, allowing vehicles to be driven or pulled (winched) onto the aircraft. This operation can be accomplished by two methods; ground loading, where the vehicle negotiates the aircraft loading ramp lowered to ground level (see Figure 2-18); or truck loading, wherein loaded vehicles are transferred from a flatbed truck or K-loader with the aircraft loading ramp supported in a horizontal position (see Figure 2-19).

For both operations, the loaded vehicles must have dimensional characteristics and axle and tire loads, which do not exceed the permissible internal dimensions of the aircraft cargo compartment and cargo door openings or the permissible weight limits of the aircraft cargo floor and ramp. The respective Technical Orders (T.O. Dash 9S) provide the permissible compartment dimensional limits and axle/tire load limits.

Ideally, air transportable vehicles do not exceed these limits and negotiate the loading ramp without exceeding allowable dimensional and weight limits. If weight limits are exceeded, shoring may be used to spread axle and tire loads to within acceptable limits.

Truckloading of air transported vehicles is used when the loading ramp angle exceeds the negotiating capability of the vehicle or causes interference between the aircraft overhead and vehicle as the vehicle enters the aircraft.

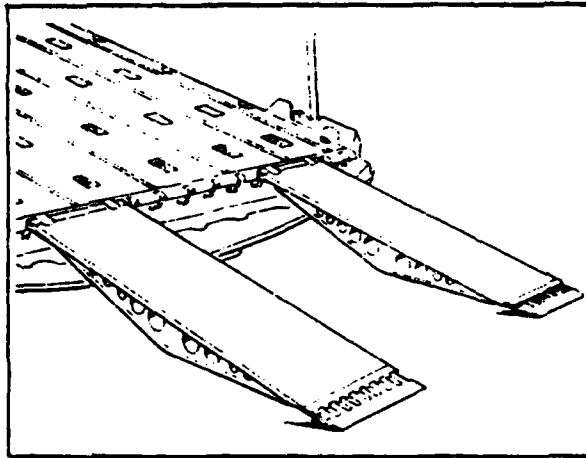


Figure 2-18 Ground Loading Ramp

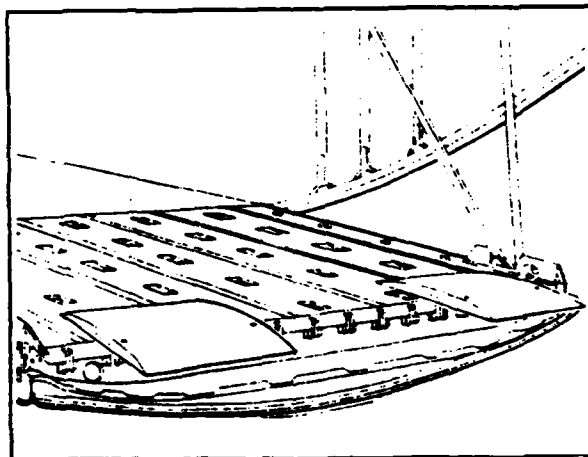


Figure 2-19 Truck Loading Ramp

Examples of these interferences are shown in Figure 2-20. A second circumstance of truckloading operations is mixed loading of aircraft, i.e., both ULDs and vehicles are included in one aircraft load complement. This "mixed load" operation permits the loading ramp to be fixed at the horizontal level, eliminating the need to lower the ramp to ground level. The "mixed load" operation is particularly advantageous with the C-5, since it eliminates the need to kneel the aircraft.

Commercial aircraft do not have loading ramps. Rolling stock is loaded/unloaded onto CRAF aircraft with an elevator loader (for widebodied main decks) or 25K or 40K loaders (for narrow-bodied main decks). Due to floor limitations, the main deck must be provided a subfloor consisting of standard 463L pallets and wood planking. Vehicles are transferred directly from elevator loader or K-loader through the main cargo door onto the 463L subfloor. Both the elevator loader and K-loader remain in a stationary aligned position at the aircraft cargo door acting as an elevating bridge (see Figure 2-21). Transfer of rolling stock to the loaders requires a ramp, typically accomplished with a CCE Low Bed Trailer with steel bridge plates to interface the trailer and loader (see Figure 2-22).

Maximum vehicles weights (unladen) which can be truck loaded are limited to the permissible axle/tire loads for the aircraft or the maximum lifting capacity of the loader (40,000 pounds for both the Cochran 316E and Wilson CL-3 Elevator Loaders and the 40K Loader). The largest military vehicle routinely loaded in the CRAF wide-bodied aircraft is the M35 Cargo Truck. The heaviest military vehicle routinely loaded is the M113 APC.

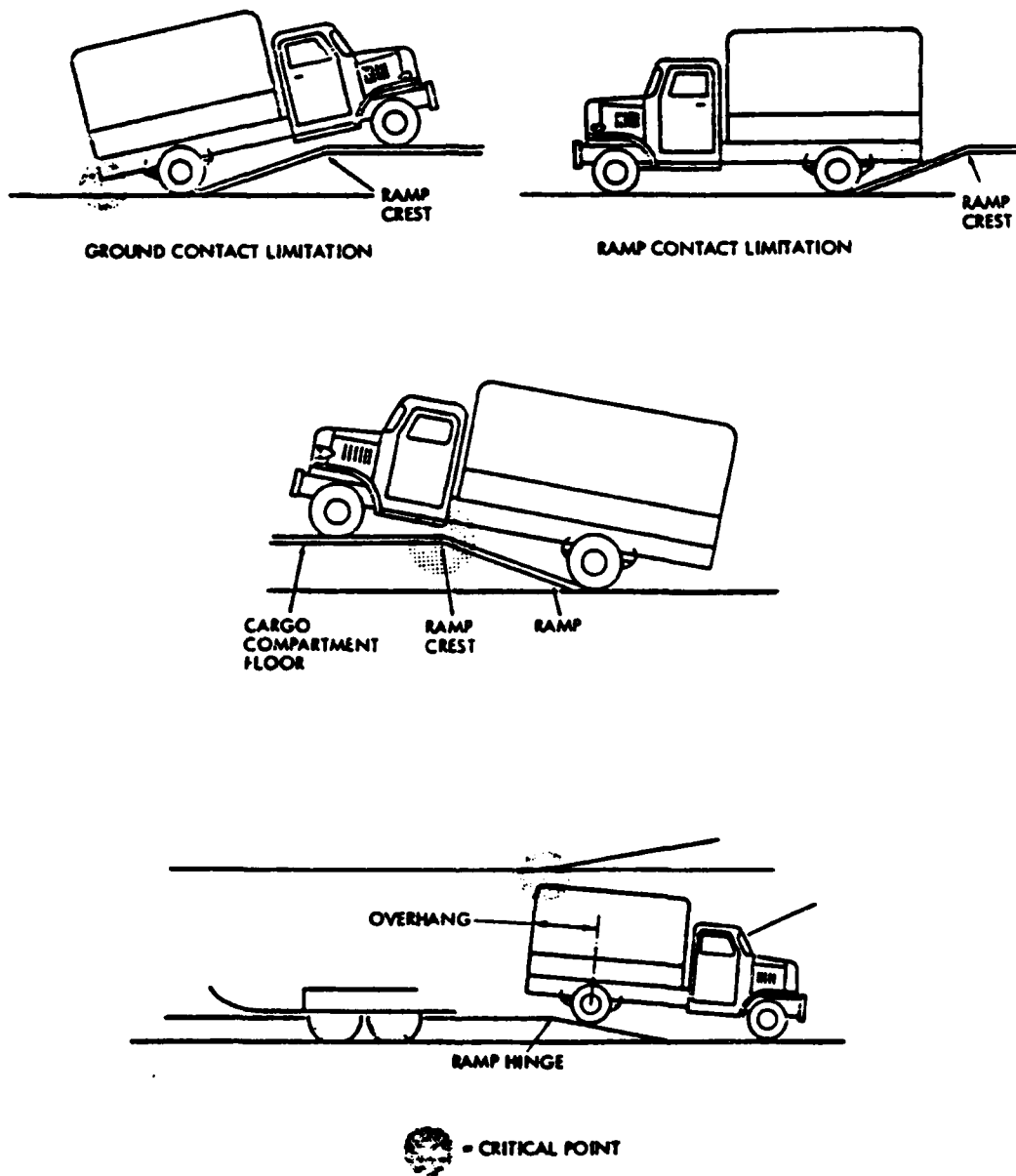


Figure 2-20 Ground Loading Interference Points

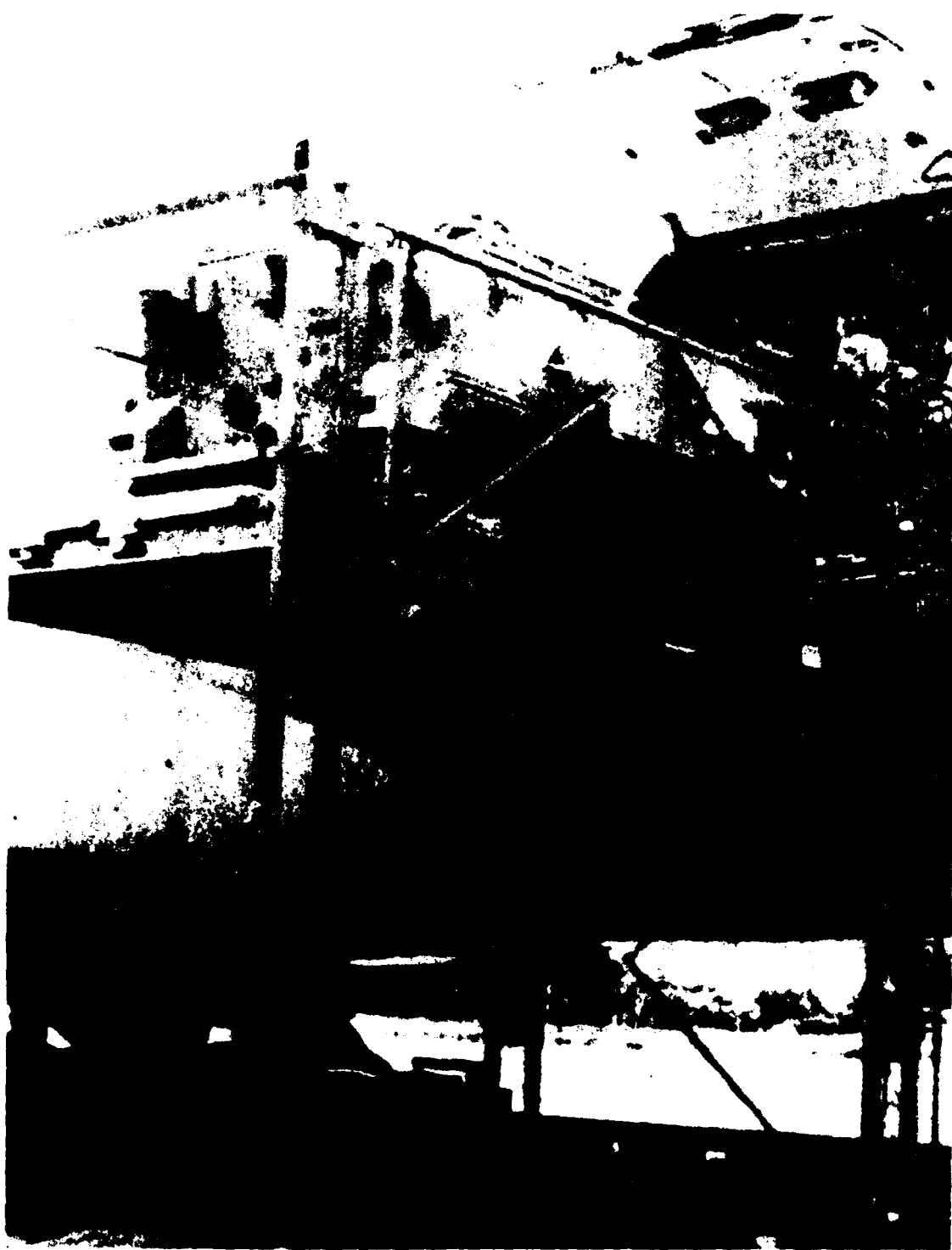


Figure 2-21 Elevator Loader/Truck Loading

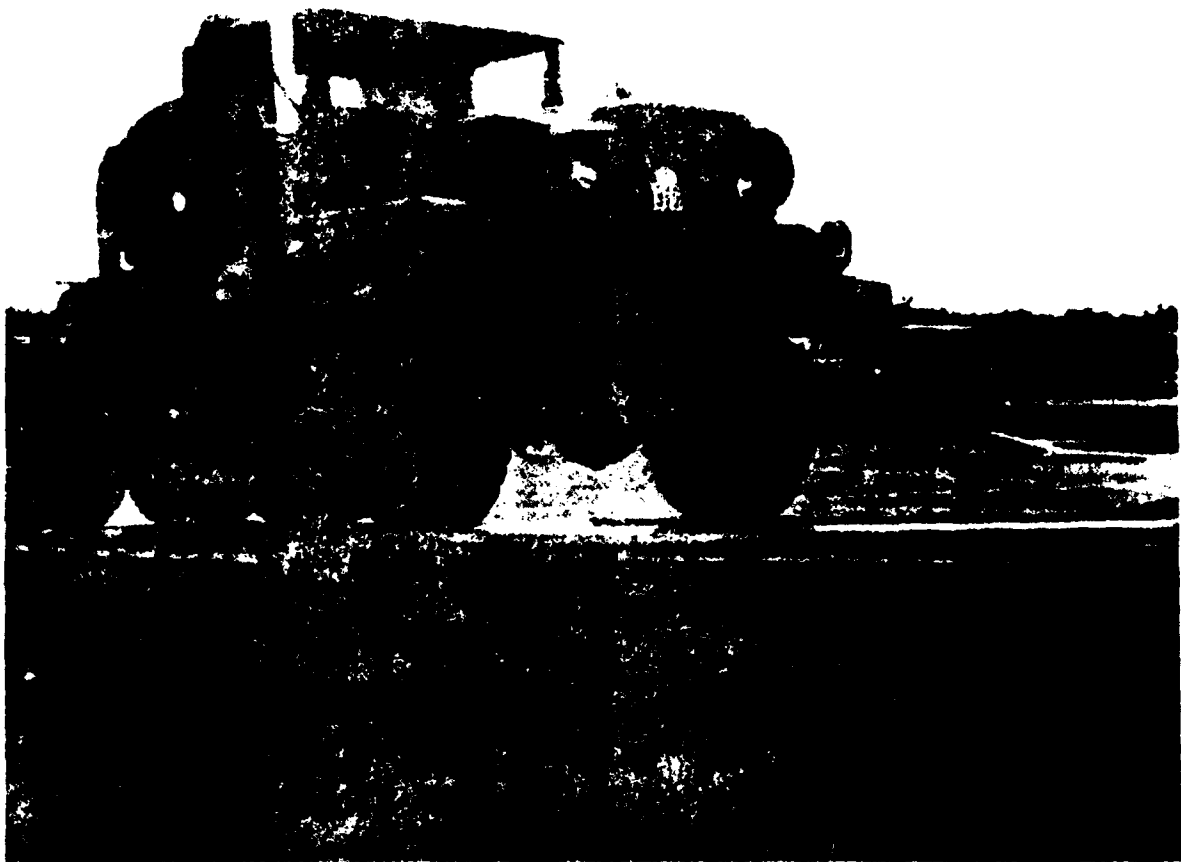


Figure 2-22 FCE Low Bed Trailer Ramp

2.1.4 Material Handling Equipment (MHE)

The cargo ground handling family of equipment (MHE) is used for the movement (and loading/unloading) of cargo between air cargo terminals (or staging areas) and aircraft. This mobile MHE has been designed (or selected) to be air transportable by these same aircraft. Equipment types included in this family are K-loaders, forklifts, elevator loaders, lower lobe loaders and trailers. Container handling equipment is in the process of being added to the family in the near future. Functions and capabilities of these MHEs are outlined in the following sections.

The original 463L System was primarily developed to be a logistics supply system, as evidenced in the central role of the HCU-6/E pallet. While retaining the basic concept of unitization, the system has evolved as dictated by expanded mission requirements and the demand for larger cargo types and ever-increasing cargo volume.

New ULDs have been added to the system, such as the airdrop and LAPES platforms, and more recently, ISO containers and shelters. Larger intercontinental CRAF aircraft have required higher cargo throughput rates and MHE performance characteristics, which are beyond the range of capabilities of the forklifts and K-loaders in the MHE family.

The remedy for these inadequacies is the addition of specialized MHE, such as the elevator and lower lobe loaders, with acquisition plans to add ISO container handling equipment to the MHE family. Even with the current low use rate, this newest ISO ULD begins to tax the cargo handling system, requiring special handling procedures.

The big benefit realized in procuring this special equipment was its immediate availability on the commercial market. These units were selected from a catalog of equipment designed to provide the same capabilities in the

commercial air freight industry. No doubt, the trade-off considerations at the time of selection favored the efficiency and economy of this equipment over that achievable by modifying the K-loaders. But in fact, the elevator and lower lobe loaders do not provide new or different material handling functions to the MHE family. They only extend the range of functional performance. The elevator and lower lobe loaders provide loading capability for the wide-bodied aircraft main deck and lower deck. The 40K loader can perform these functions, but with costly and inefficient modifications and the need for ancillary equipment. (See paragraph 2.1.4.1).

In retrospect, this method of supplementing the MHE family with new members is seen to have sufficed in "filling the gap" in the functional performance shortfall. But the trend toward a proliferation of the system with a multiplicity of equipment types begins to compromise and erode the USAF's ability to complete the airlift mission, i.e., to deploy (and supply) combat forces to distant and varied locations throughout the world. The total mission requirements for the MHE follows from the overall airlift mission requirement. The MHE must be deployed to the distant and varied locations throughout the world to provide the cargo ground handling capability at those locations. Therefore, the MHE must be air-transportable. Ideally, the air-transportable MHE is a single asset; one multi-purpose MHE that must be air-transported. As such, it requires a minimum amount of the limited and valuable airlift capability, yet has the advantage of self-sufficient utility to perform the required cargo-handling work functions.

And just as importantly, costs associated with life-cycle management is reduced in proportion to the reduction in number of equipment types in the MHE system.

2.1.4.1 K-Loaders (Aircraft Loading/Unloading Trucks) The K-loader family consists of the 40K loader, 25K loader, and the TAC loader. The 40K and 25K loaders are primarily used at established aerial ports, on terrain which has paved surfaces with minimal gradients. The TAC loader is designed for rough terrain use at forward operating bases, as well as established bases.

The 40K loader is the workhorse. It has the highest capability (40,000 pounds) and handles the most volume (five 463L pallets) in one payload. The TAC loader is the only one of the three loaders which has rough terrain capability with its all wheel drive and twin bogie suspension.

Air transportability is provided by the C-130 for the 25K and TAC loader; the C-141B is required for the 40K loader. (See paragraph 2.3.2).

Detailed specifications of the 40K, 25K and TAC loaders are contained in Figures 2-23, 2-24 and 2-25, and Tables 2-2, 2-3 and 2-4.

The K-loaders are the primary ATLs used by the USAF. Among the MHE included in the cargo ground handling family, the K-loaders are singularly designed for transport and loading of 463L-configured cargo onto aircraft. This functional statement contains two important basic elements. As a transporter, the K-loader carries a full payload of cargo from a staging area to the aircraft. It is a cargo truck, with highway (and off-highway) mobility and maneuverability. As a loader, cargo can be rolled on to the conveyor bed and be restrained and locked, for transport to an aircraft. Deck functions provide for positioning and aligning the loader deck with the aircraft cargo door and deck for direct, easy transfer to and from the aircraft cargo compartment.

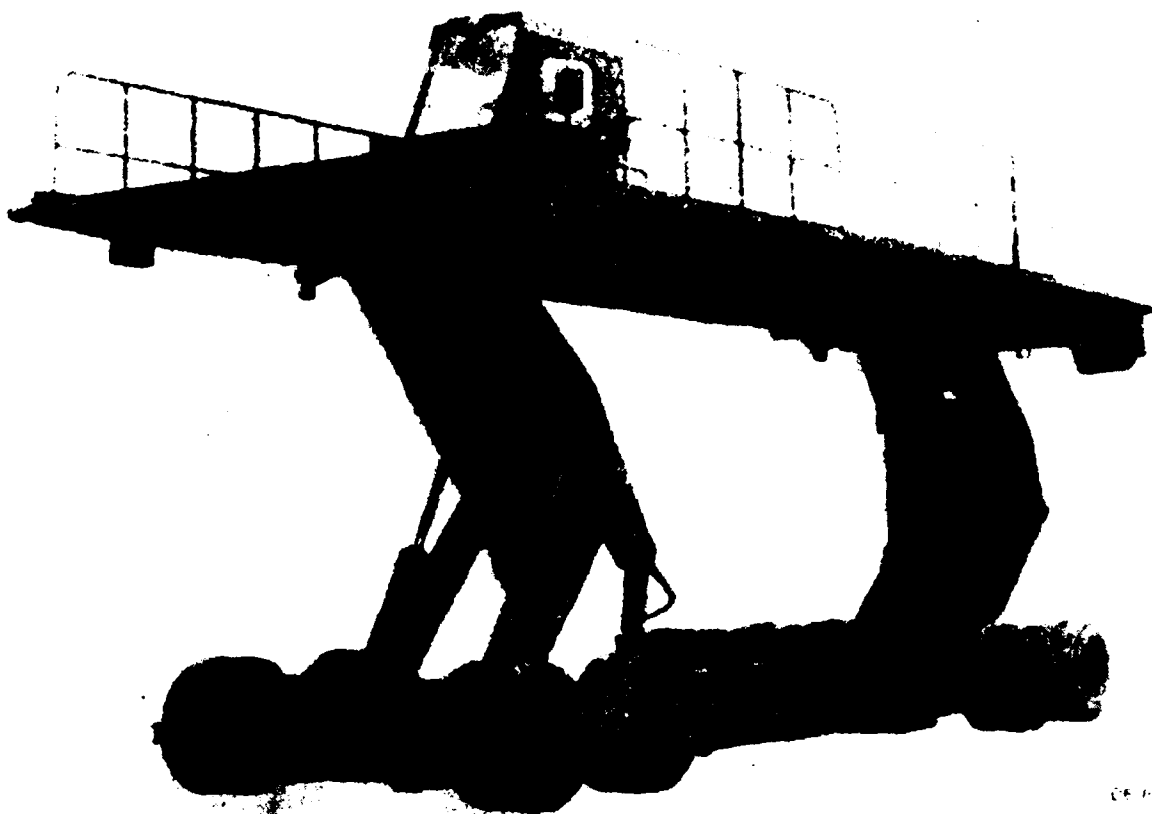


Figure 2-23 40K Loader

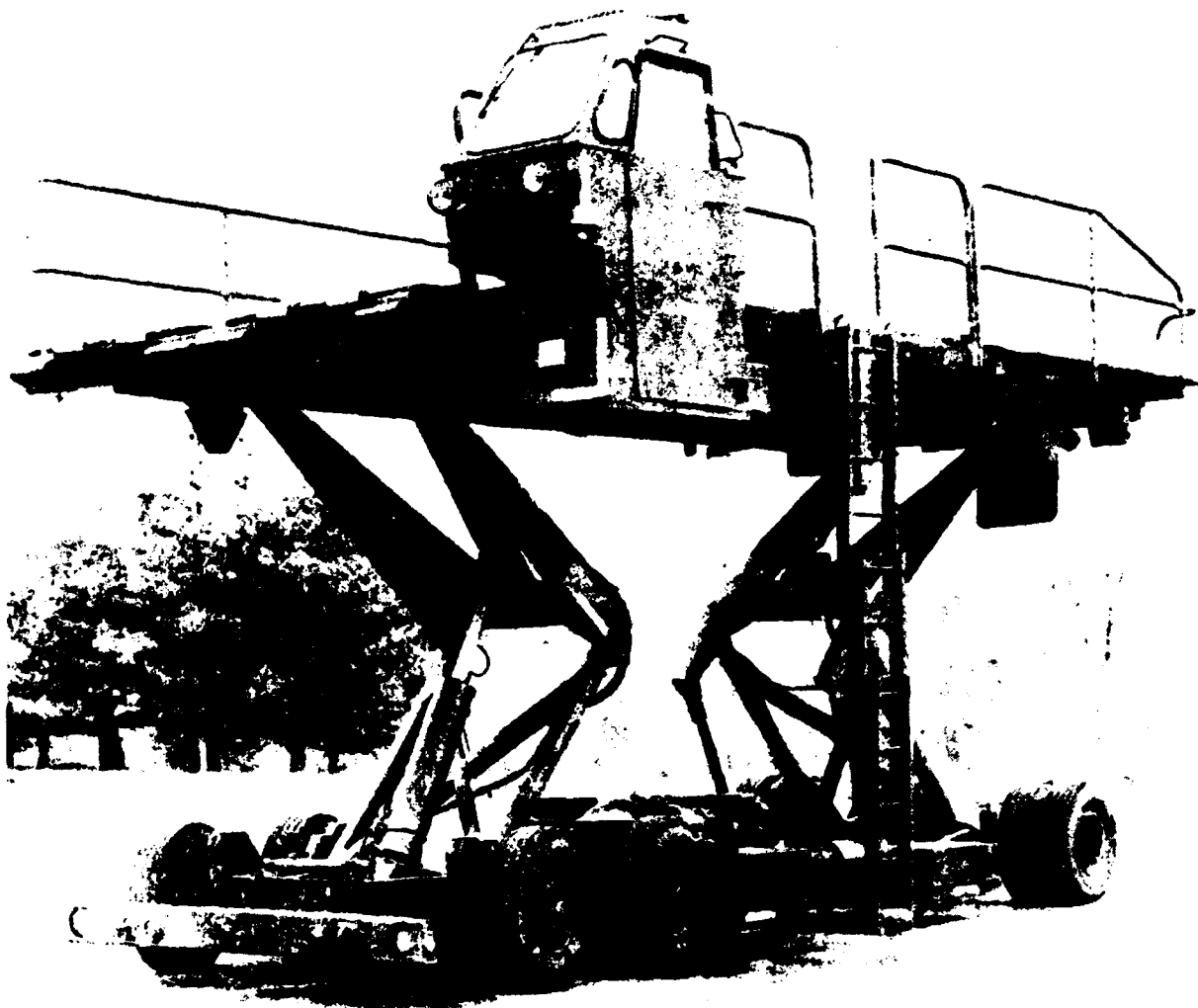


Figure 2-24 25K Loader

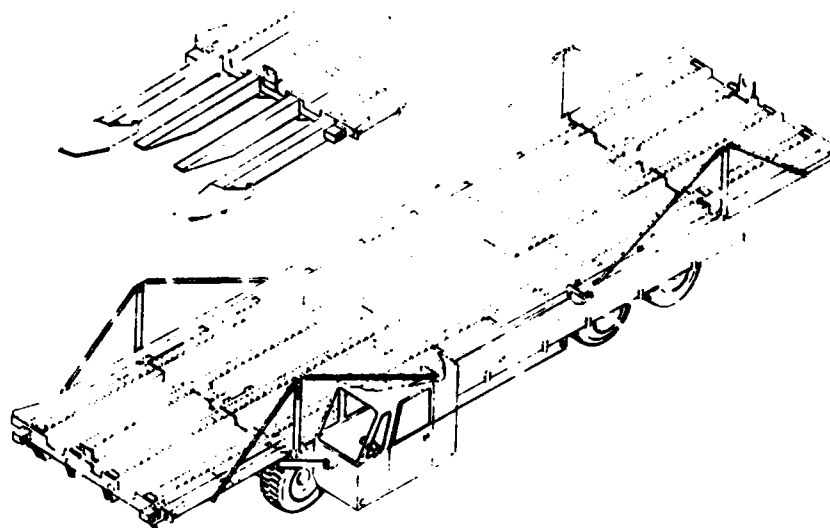
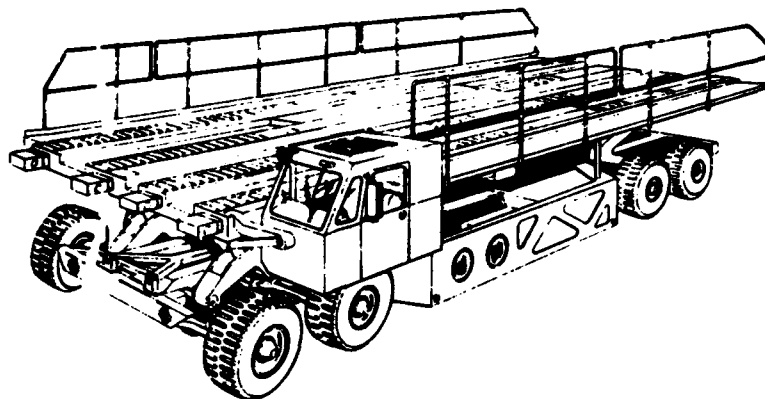


Figure 2-25 TAC Loader

Table 2-2 40K Loader Specifications

GENERAL	
Vehicle Type	USAF Type A/S32H-6A, Aircraft Cargo, Loading/Unloading Truck
Overall Length	497 inches
Width (operational)	155 inches
(reduced for shipping)	120 inches
Operating Temperature Range, Ambient	-40°F to +120°F
Loading Height of Cargo Deck	41 inches to 156 inches
Deck Height (on travel rest mechanisms)	49 inches
Deck Height (on maintenance supports)	84 inches
Cab Height Above Cargo Deck	32 inches
Design Load Capacity	40,000 pounds
Empty Vehicle Weight	44,000 pounds
Gross Operational Weight	84,000 pounds
Deck Roll (left or right)	4° maximum
Deck Pitch (front to rear)	6° maximum
Deck Side Shift (left to right)	1.75 inches
Top Speed (loaded)	15 mph fwd
Top Speed (deck on travel rest mechanisms)	5 mph rev
Gradeability	3% @ 12 mph, full load
Towing Speed	3 mph
Turning Radius (loaded)	40 feet
Ground Clearance (normal operation)	7.5 inches

Table 2-3 25K Loader Specifications

GENERAL

Vehicle Type	USAF Type A/S32H-5A, Aircraft Cargo, Loading/Unloading Truck
Gross weight (unloaded)	22,500 LB (wet)
Overall length (fingers lowered)	322 inches
Overall width (cab stowed, catwalks off)	110 inches
Chassis clearance	
Suspension lowered	5 inches
Suspension normal	7.75 inches
Suspension raised	14 inches
Platform height	
Raised	156 inches
Lowered	37.5 inches
Platform Dimensions	
Width at cab	147-1/2 inches
Width across back	128 inches
Width across back w/o catwalk	109-7/8 inches
Length	336 inches
Distance between guide rails	108-3/8 inches minimum
Distance between guide rails	108-1/2 inches maximum
Maximum speed	25 MPH
Maximum continuous load	25,000 LB

Table 2-4 TAC Loader Specifications (Sheet 1 of 2)

PAYLOAD, Basic Truck

Load A, HCU-6/E Pallets, total	3
One pallet maximum	10,000 lbs
Maximum weight	25,000 lbs
Load B, Distributed Weight	25,000 lbs
Load C, 20-foot Air Drop Platform	1
Maximum weight evenly distributed, main deck	36,000 lbs
Load D, Front or Rear Deck Half	
Maximum evenly distributed load	18,000 lbs

PAYLOAD, Truck with Kit

Load D, HCY-6/E Pallets, total	3
One pallet center	9,000 lbs
One pallet front or rear extension	10,000 lbs
One pallet front or rear extension opposite to 10,000 lb pallet	6,000 lbs
Maximum total load	25,000 lbs
Load F, HCUC-6/E Pallets, total	4
One pallet front extension	6,000 lbs
One pallet rear extension	6,000 lbs
Two pallets main deck	6,500 lbs
Maximum total load	25,000 lbs

MOBILITY

Load A or B, as above	
Speed, forward and reverse, adverse terrain	5 mph
Speed, 10 percent grade, paved surface	5 mph
Speed, 3 percent grade, paved surface	10 mph
Speed, level paved surface	15 mph
Load C, as above	
Speed, level paved surface, 3-degree side slope	5 mph
Kneeled Mode - aircraft itnerface, less than	1 mph
Stopping Distance, dry concrete	
At 15 mph, 25,000 lb load	15 ft

Table 2-4 TAC Loader Specifications (Sheet 2 of 2)

GROUND CLEARANCE	
Kneeled Mode, at frame - loaded	3.5 in
- unloaded	4 in
Operational Mode, at frame	13.5 in
Axles	8 in
DECK MOVEMENT	
Kneeled Height	39.75 in
Operational Height, raised	75 in
Pitch, front and rear	5 deg min
Roll, right and left	5 deg
Maximum Vertical Travel Rate with 25,000 lb load	50 sec
DECK SURFACE LOADING	
Distributed loads	500 psf max
Local loads	50 psi max
CARGO WINCH	
Usable Cable	150 ft
Speed, single line, outer wrap	30 fpm
Single Line Pull, inner wrap	4,500 lbs
Overload Protection, maximum pull	4,950 lbs
VEHICLE WEIGHTS	
Basic Truck, with limited consumables	25,555 lbs
Basic Truck, with kits and consumables	27,800 lbs
GROSS OPERATIONAL WEIGHTS	
Basic Truck	50,550 lbs
Truck with Kits	52,800 lbs
Truck with Kits, maximum load	63,800 lbs

In summary, the K-loaders are self-sufficient in loading/unloading aircraft and in delivering cargo to and from the aircraft. They have the added versatility of being loaded by top-loading MHE. This self-sufficiency is an essential characteristic to its function.

Different types of cargo ULDs have not limited the K-loader simply because new ULDs were designed to fit the system (which is really a constraint of the aircraft system) or the ULDs are provided an adapter or HCU-6/E pallet base.

There is a limit, though; the current K-loader family cannot service the wide-bodied aircraft. The maximum elevated deck height of the 40K and 25K loaders is 13 feet. The main cargo deck height of the B747 and DC-10 (KC-10) are nominally 17 feet and 18 feet. The lower lobe deck heights of the wide-bodied aircraft are within the range of the 40K and 25K, but the aircraft cargo door opening cannot be accessed due to interference between the aircraft fuselage and the loader operator's cab and safety handrail. See paragraph 2.3.1.1.

To overcome the main deck height limitation, a deck adapter is used with the 40K loader (see Figure 2-26). Lifting capacity is reduced by an amount equal to the weight of the adapter. Operator visibility of the cargo door and adapter interface is impaired and loader stability in both the driving and loading mode is reduced because of the heightened location of the center-of-gravity. Although the adapter extends the operational capability of the 40K loader, it is apparent that the disadvantages begin to outweigh the limited benefits realized and the self-sufficient capability is lost.



Figure 2-26 40K Loader with Adapter

A second solution to the height problem is the elevator loader (see paragraph 2.1.4.3). The elevator loader is preferred over the adapter-equipped 40K loader. The operator visibility and stability problems are removed, but K-loaders are still required for transport and load transfer to and from the elevator. But the elevator loader is not an optimal solution. It is another specialized piece of equipment with limited application in the 463L System. Self-transport and air-transport capabilities are limited and reliability/maintainability are minimal.

Lower lobes of wide-bodied aircraft are serviced by a 40K loader with a specially designed bridge (see Figure 2-27). The bridge spans the gap between aircraft deck and loader deck, allowing the K-loader to stand-off away from the aircraft fuselage. The bridge is designed for LD-3 containers and can handle ULDs of similar size and weight; it is too narrow for the 463L pallet. Although, the bridge extends the capability of the 40K to lower lobes, it imposes the added inefficiency of handling of the bridge for this specialized service and does not provide capability for 463L pallet loading in lower lobes. For these reasons they have limited use.

Lower lobe loaders have been purchased to provide this capability, but the same arguments apply as noted earlier for specialized equipment.

2.1.4.2 Forklifts. The three primary forklifts used in the system have a capacity of 10,000 pounds. They are commonly referred to as the 10K Standard, the 10K Heavy Duty and the 10K Adverse Terrain. All three were selected and are used for the 463L pallet.

The 10K Standard is used in air freight terminals for bulk cargo handling, loading and unloading the K-loaders and aircraft. It requires paved and level surfaces for operation.

The 10K Heavy Duty forklift is a Hyster Model H100A-48-AF. It is a commercially available unit, which can be used for the same operations as the 10K Standard with the added capability of operating on all but soft or muddy terrain. The 10K heavy duty forklift is an older model with few units in service. The 10K Adverse Terrain is a commercial Euclid Model 72-20. With four-wheel drive, it is used at forward combat bases in conjunction with the TAC Loader. Both the 10K Heavy Duty and 10K Adverse Terrain forklift are air-transportable. Loading/unloading of K-loaders is a key function of the 10K forklifts. For this purpose, the K-loaders have forklift time troughs

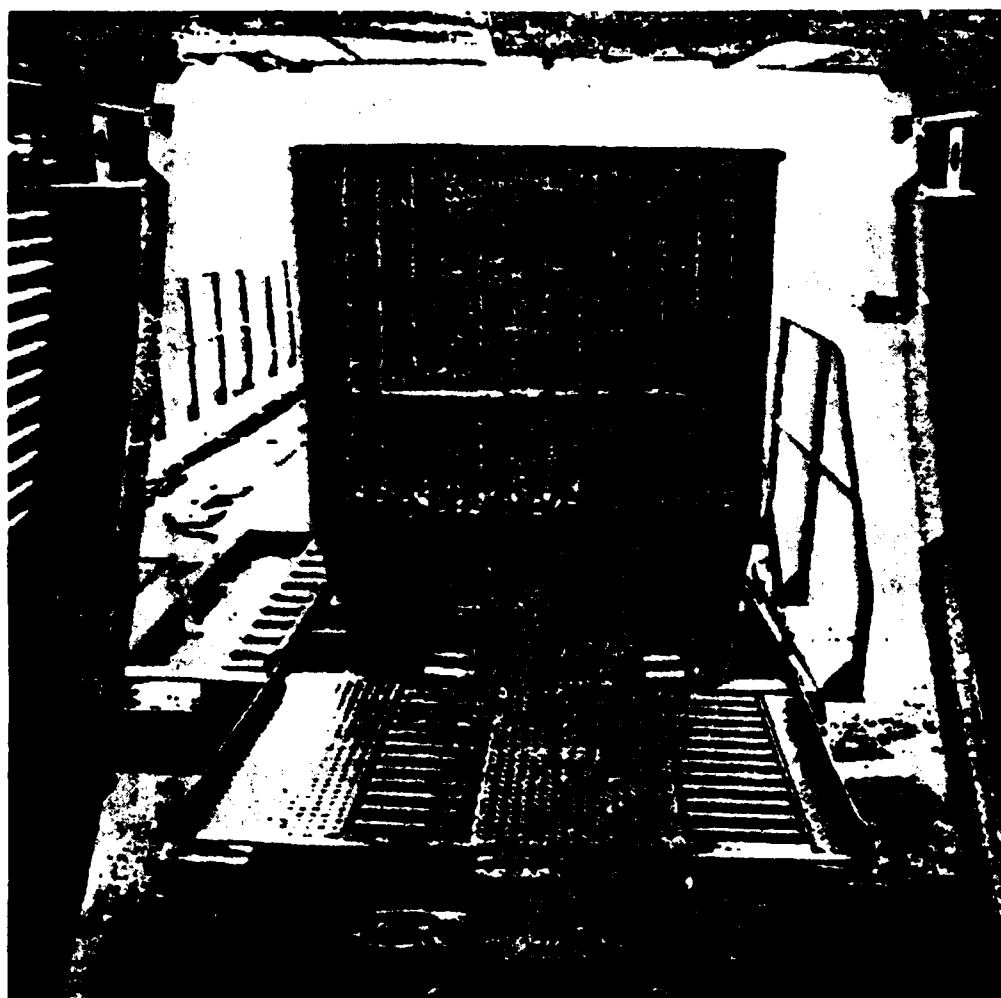


Figure 2-27 40K Loader Bridge Device

recessed into their deck. The troughs are located at the rear of 40K and older 25K loaders, the rear and side of the newer 25K loader, and the front and rear of the TAC loader. Loading of pallet and platforms by forklift at the recessed access points is both easy and safe. Loading of airdrop platforms by forklift onto the K-loaders is sometimes done from the side, because of the platform size.

The newest member of the forklifts is the 15K Model H150B. It has a 15,000 pound capacity and a maximum lift height of 17.5 feet.

The forklifts can be used to load aircraft, but this function is usually relegated to the K-loader. The hazard of loading aircraft with forklifts are obvious and unfortunately well-established.

Lower capacity forklifts in the 463L system are the 4K and 6k forklift. The 4K Lowmast is used in air freight terminals for handling bulk cargo in pallet preparation. It seldom interfaces with K-loaders. The 6K forklifts are few in number, originally designed and used for the HCU-12/E half-pallet.

2.1.4.3 Special Loaders. The special loaders are the elevator and lower lobe loaders. The need for their special function was discussed under previous sections. Although these loaders have a function in the current system, both self-sufficiency and utility of a future ATL will be considerably improved if its performance capabilities include the function of these specific loaders, i.e., service wide-bodied main and lower decks.

The elevator loaders used are the Cochran Models 316A and 316E and the Wilson Model CL-3. The 316A has a maximum capacity of 25,000 pounds; the 316E and CL-3 have a maximum capacity of 40,000 pounds. Maximum elevation height of the 316A and E is 18 feet; 18.5 feet for the CL-3.

None of these loaders is a transporter. Mobility is limited to maneuvering the loader into position at aircraft cargo doors to act as an elevator bridge. Cargo is delivered to the elevator loader by a K-loader or roller-bed trailers. The elevator loaders also serve to load rolling stock, which are driven onto the platform by means of a ramp (see Figure 2-22). Specifications for the three elevator loaders are contained in Table 2-5.

The lower lobe loader is the Transact Model TA15. Maximum lifting capacity is 15,000 pounds with a maximum elevation height of 11.6 feet. It is a lower deck loader with capability to service other narrow bodied aircraft (B707, B727, DC-8). Like the elevator loaders, the lower lobe loader is not a transporter; it is used as a bridge, once positioned and interfaced with the aircraft.

2.1.4.4 Trailers. Trailers are used as an efficient and inexpensive means to transport cargo within an air freight terminal complex. Two basic types are used: palletized cargo trailer and flat-bed semi-trailers. The palletized cargo trailer (A/M32H-6) is a roller-bed dolly, which can handle and provide mobility for one HCU-6/E pallet. The BCU-6/E spotter tractor is used to maneuver the pallet dolly. The dollies cannot interface with the K-loaders, since the bed height is below the deck elevation range of the K-loader. Forklifts are used to unload dollies in this operation.

Flat-bed semitrailers, such as the M270, M871 and M872, provide greater capability because of their higher payload and their cargo beds can be reached by the K-loaders. Removable roller conveyor kits are used on the trailer beds for easy cargo transfer to K-loaders. This semitrailer transport capability is most advantageously used for airdrop operations. Fully rigged airdrop platforms, prepared at a distant site from aerial loading operations, can be

Table 2-5 Elevator Loader Specifications

<u>MODEL</u>	<u>COCHRAN 316A</u>	<u>COCHRAN 316E</u>	<u>WILSON CL4</u>
Overall Length:	288 Inches	296.5 Inches	305 Inches
Overall Width:	183.75 Inches	237.75 Inches	238 Inches
Overall Height:	21 Feet	21 Feet	22.75 Feet
Platform Height:			
Maximum	18 Feet	18 Feet	18.5 Feet
Minimum	19 Inches	19 Inches	19 Inches
Platform Width:	128 Inches	128 Inches	128 Inches
Platform Length:	252 Inches	268 Inches	285 Inches
Platform Capacity:	25,000 Lbs	40,000 Lbs	40,000 Lbs
Weight (Assembled):	19,100 Lbs	19,500 Lbs	26,440 Lbs
Ground Speed (Self-Propelled)			
Low	1 MPH	1 MPH	1 MPH
High	2.5 MPH	2.5 MPH	2.5 MPH
Ground Speed (Towed):	5 MPH	5 MPH	5 MPH
Power:	Gasoline/Hyd.	Diesel/Hyd.	Diesel/Hyd.
Air Transport:	Disassembled	Disassembled	Disassembled
	C-130, C-141B,	C-130, C-141B	C-130, C-141B
	C-5, KC-10,	C-5, KC-10,	C-5, KC-10,
	DC-10, B-747	DC-10, B-747	DC-10, B-747

delivered by the semitrailer to a staging area for rapid transfer to a K-loader. With equal ease, semitrailers can deliver ULDs to a K-loader positioned at an aircraft, which essentially acts as a bridge link between trailers and aircraft.

2.1.4.5 Container Handling Equipment (CHE). The USAF plans for container handling equipment includes 50,000 pound and 75,000 pound capacity straddle cranes; 22,000 pound capacity forklifts; container side-loading semitrailers; and 35-ton bridge cranes. Each of these CHEs are primarily intended for container/shelter handling, and several are in service at major port bases. Except for the 22K forklift, all are typically top-loading equipment. None have aircraft loading capability. In the airlift mission, they serve the same purpose as the forklifts, i.e., load/unload the ATL for transport and loading/unloading of aircraft.

2.1.5 Cargo Aircraft

Cargo aircraft used for military purposes are, in times of peace and contingency, a mixture of both military and commercial aircraft.

Faced with the escalating costs of new aircraft and the budgetary restraints imposed by reductions in military spending, the Military Air Command (MAC) is burdened with the awesome task of increasing contingency inter-theatre airlift capability to 66 million ton-miles per day from the current 32 million ton-miles per day capacity. The resources available to MAC are:

1. An aging cargo fleet (including Air National Guard and Air Force Reserve Aircraft) consisting of the C-130, C-141 and C-5 aircraft.
2. The C-17 Inter and Intra-theatre cargo military aircraft, which is tentatively scheduled for initial operational capability in FY'92.

3. The Civil Reserve Air Fleet (CRAF), which has become an equal member, so to speak, of the airlift family as it provides half of the USAF's long-range capability during contingencies.
4. The Military Airlift Command and the Aeronautical Systems Division are currently laying the groundwork for the Advanced Tactical Transporter. This aircraft will replace the C130 in the tactical airlift role early in the next century.

The following sections describe the various aircraft used in the MAC system along with cargo interface characteristics.

2.1.5.1 USAF. The U.S. Air Force Cargo Fleet for inter-theatre missions currently consists of approximately (271) C-141 and (69) C-5 aircraft. Intra-theatre cargo missions are delegated to the (362) C-130 aircraft. These aircraft can be supplemented by some (312) C-130s, (16) C141Bs and (8) C-5s currently assigned to the Air National Guard and Air Force Reserves. With the introduction of the C-17 aircraft in the mid-1990s, the USAF will have additional inter and intra-theatre capability.

SAC and TAC rely upon the KC-10 Advanced Tanker Cargo Aircraft (ATCA) for in-flight refueling as well as cargo transfer. This aircraft which devotes the lower deck to fuel containment, is capable of transporting up to 170,000 pounds of cargo in the main deck.

Cargo related characteristics of the above USAF aircraft are described in the following sections.

2.1.5.1.1 C-130. The C-130 is a four engine, turboprop, high wing aircraft manufactured by Lockheed-Georgia Company. Designed for primarily tactical intra-theatre missions the C-130 has been used for airdrop loads in excess of 36,000 pounds. The aircraft is divided into two pressurized and air conditioned compartments consisting of a flight station and a cargo compartment.

There is a crew door on the forward left hand side of the aircraft; two para-troop doors aft, one on each side of the airplane; and an aft cargo door and ramp that opens from the rear of the aircraft.

The cargo compartment provides a cargo space nominally 41 feet long, 123 inches wide and 108 inches high. The cargo floor is equipped with a 463L roller conveyor system, which consists of rollers, guide rails and locks.

The aft cargo door and ramp can be opened to almost the full size of the cargo compartment. The cargo ramp is actuated by two hydraulic cylinders and can be stopped in any position between closed and open. When fully open, the ramp can be used for roll-on/roll-off loading of vehicles by attaching two auxiliary ground loading ramps (supplied with aircraft). When interfacing with a cargo loader, the ramp will be in the horizontal position.

Cargo Related Information

- The C-130 can accommodate 6 standard 463L freight pallets.
- Maximum freight capacity is approximately 43,400 pounds.
- 463L Roller system permits loading of metric LAPES platforms with skids attached.
- For additional information on cargo door opening and roller configuration, refer to Figure 2-28.

2.1.5.1.2 C-141B. The C-141B is a high-swept back-wing jet aircraft powered by four turbofan jet engines. Manufactured by Lockheed-Georgia Company, the C-141B is designed for the inter-theatre mission. The cargo compartment is nominally 93.3 feet long, 123 inches wide and 109 inches high. The cargo floor is equipped with four longitudinal roller tracks which can be placed with the rollers up or inverted to stow the rollers in the floor. These rollers are part of the 463L conveyor system, which includes rollers, guide rails and locks.

The aft end of the cargo compartment contains a pressure door and ramp, which seal the compartment during pressurized flight. Two petal doors in conjunction with the ramp and pressure door can be operated for airdrops or on

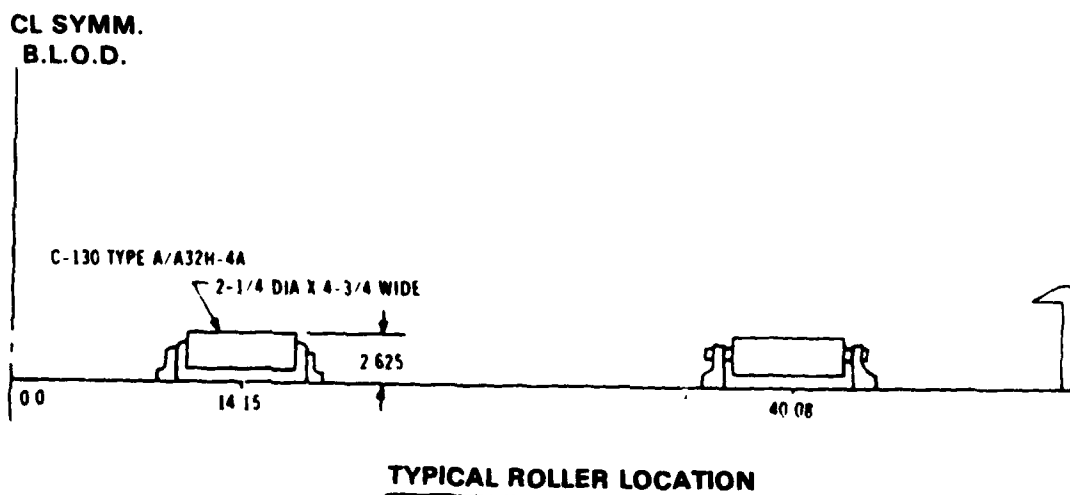
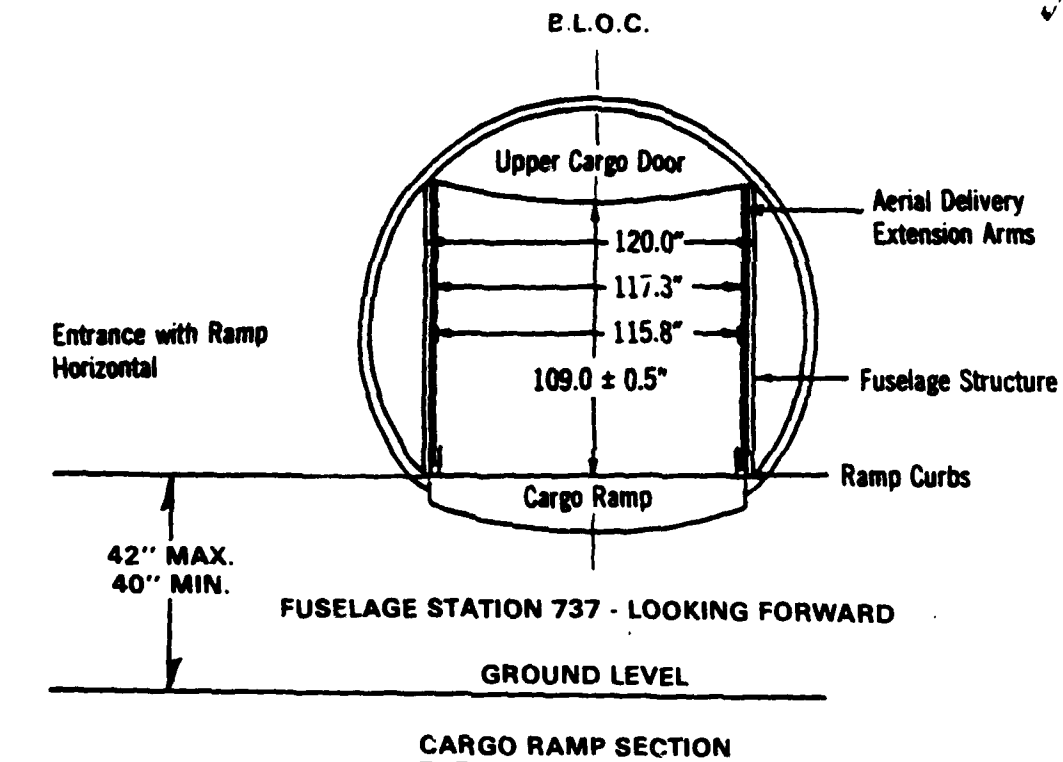


Figure 2-28 C-130 Characteristics

the ground to permit straight in loading of the compartment. The ramp is rotated downward to (1) a horizontal position for straight in-loading or an air-drop position or (2) an inclined down position where it serves as a ground loading ramp making an angle of approximately 15° with the ground.

Cargo Related Information

- The C-141B can accommodate 13 standard 463L pallets.
- Maximum freight capacity is approximately 90,000 pounds
- 463L System does not permit loading of metric LAPES platforms with skids attached, as skids are too deep to allow platform contact with rollers.

For additional information on cargo door opening and roller configurations refer to Figure 2-29.

2.1.5.1.3 C-5. The C-5 is a high speed, high capacity long range aircraft powered by four turbofan jet engines. Manufactured by Lockheed-Georgia Company, it is designed for strategic inter-theatre transportation of cargo and troops. The C-5 requires a crew of five and can accommodate a complement of 345 troops or an equivalent mix of troops, vehicles and supplies.

The cargo compartment provides a cargo space nominally 121 feet long, 228 inches wide and 162 inches high. The cargo floor is equipped with a dual set of 463L roller conveyor systems complete with rollers, guide rails and locks. The rails and rollers can be stowed in the aircraft floor providing a flat floor. The floor is designed for full width load bearing and does not have specific treadways.

This aircraft is provided with both fore and aft cargo doors and ramps. Access to the forward cargo opening is achieved by raising a hydraulically actuated hinged visor. Access to the rear cargo opening is achieved by

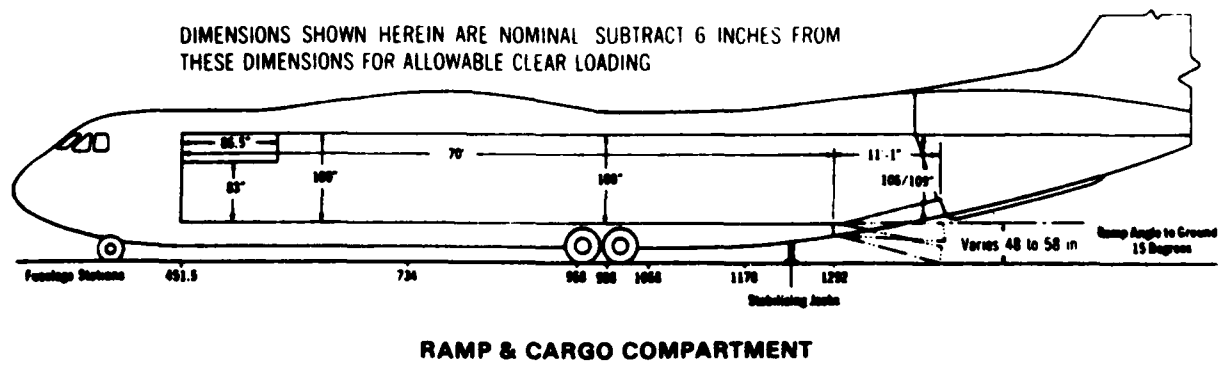
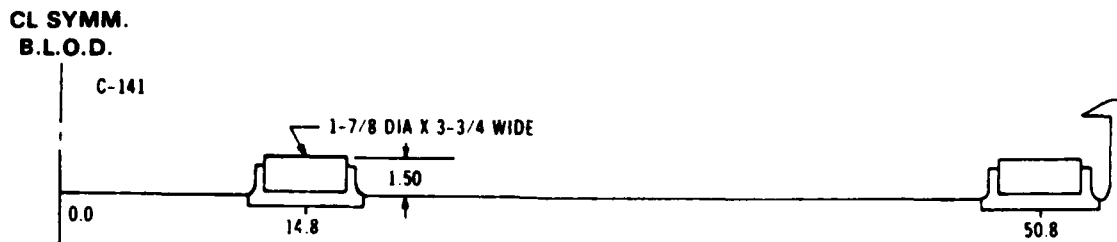
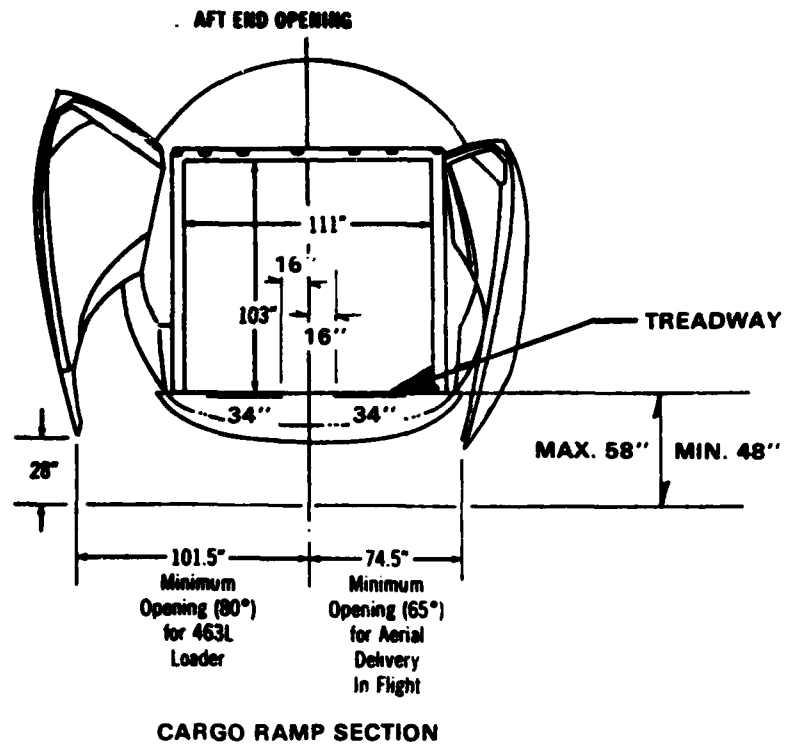


Figure 2-29 C-141B Characteristics

hydraulically actuating the aft pressure door, the center cargo door and the two side cargo doors to the open position. This aircraft can be kneeled to various heights for both fore and aft ramps. Cargo can be loaded from loaders, trucks or driven on/off.

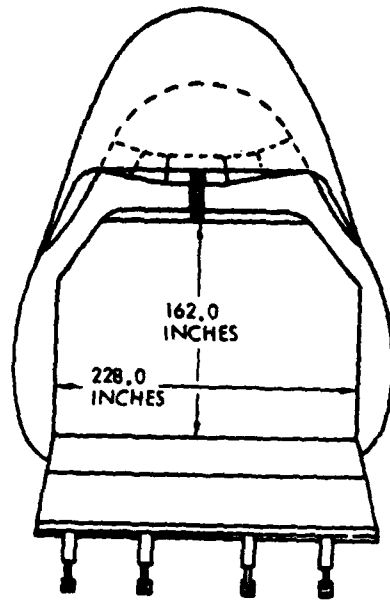
Cargo Related Information

- The C-5A can accommodate 36 standard 463L pallets.
- Maximum freight capacity is approximately 261,000 pounds.
- 463L roller system does not permit loading of metric LAPES platforms with skids attached as skids are too deep to allow platform contact with rollers.
- For additional information on cargo door opening and roller configuration, refer to Figure 2-30.

2.1.5.1.4 C-17. The C-17 is a heavy lift, air refuelable cargo transport powered by four turbofan jet engines. Developed by McDonnell Douglas Corporation, the C-17 is able to provide inter-theatre and intra-theatre airlift of outsize combat equipment, including the M1 tank, directly into airfields in potential combat areas. This aircraft will be used for LAPES and airdrop loads, and indeed, is the only aircraft capable of airdropping outsized firepower such as the U.S. Army's infantry fighting vehicle.

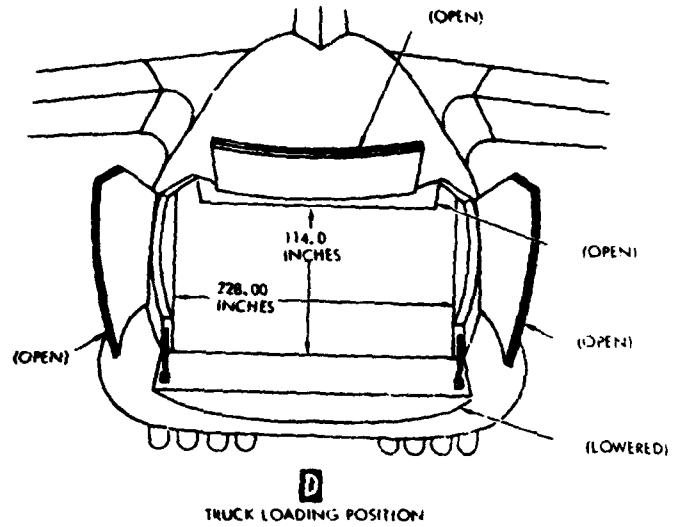
The cargo compartment, which features a loading ramp/door in the underside of the rear fuselage is nominally 88 feet long (includes rear loading ramp), 216 inches wide and 142-162 inches high. Cargo hold equipment includes rails, locks and roller conveyors to accept standard 463L pallets.

The cargo door and ramp can be opened to the full size of the cargo compartment. The cargo ramp is hydraulically actuated and can be used when fully



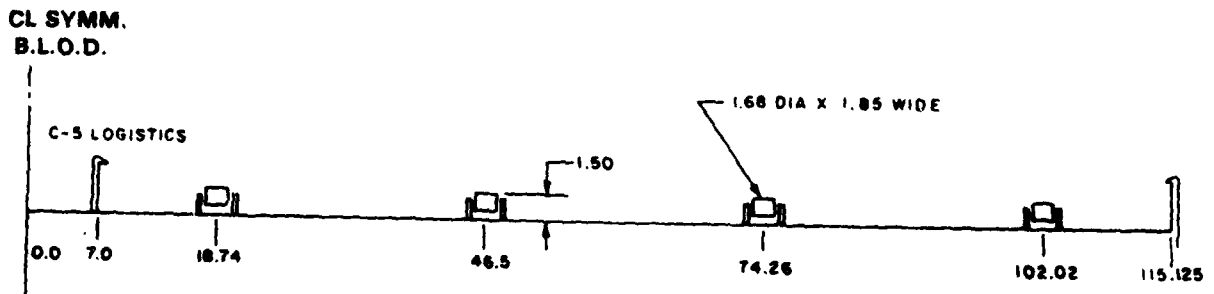
TRUCK LOADING POSITION

FORWARD CARGO OPENING



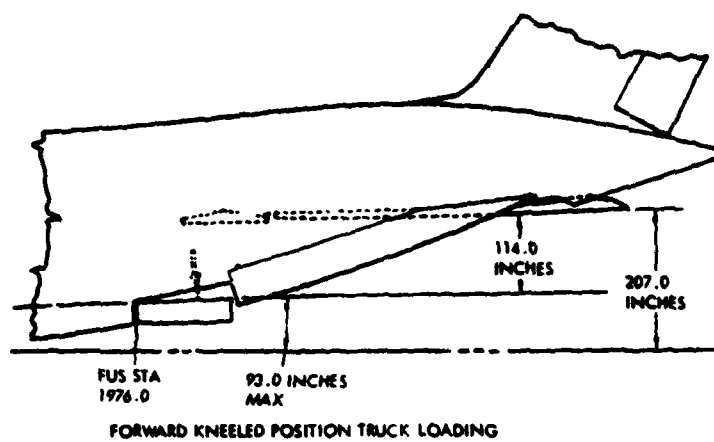
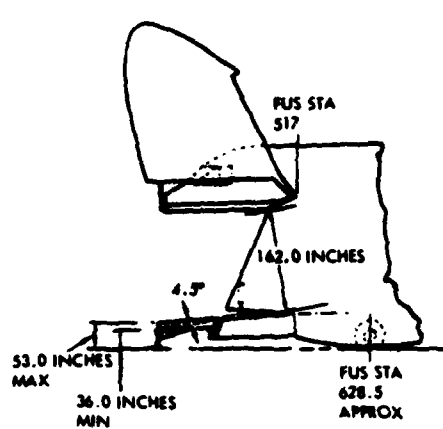
TRUCK LOADING POSITION

AFT CARGO OPENING

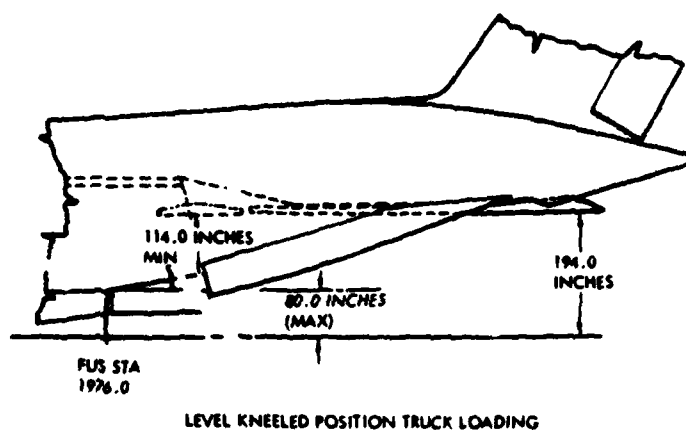
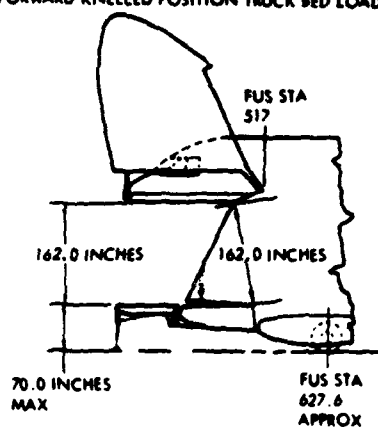


TYPICAL ROLLER LOCATION

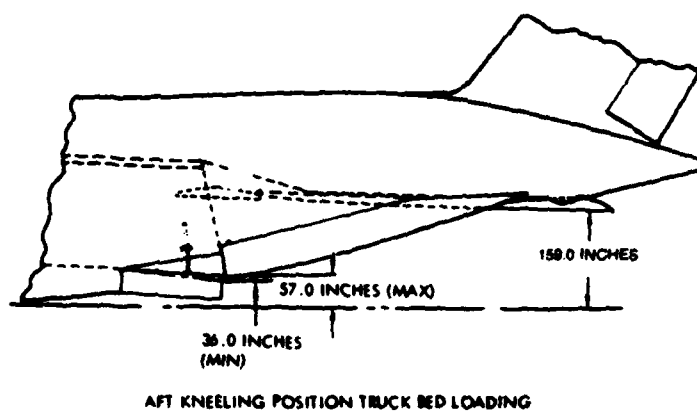
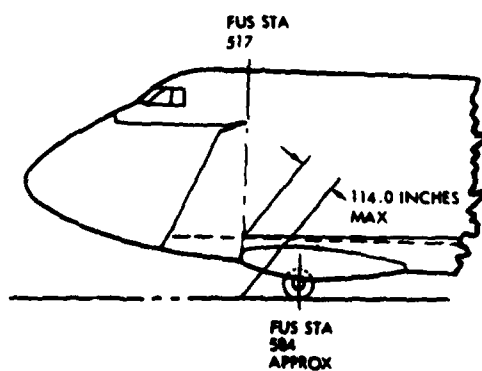
Figure 2-30 C-5 Characteristics (Sheet 1 of 2)



FORWARD KNEELED POSITION TRUCK BED LOADING



LEVEL KNEELED POSITION TRUCK BED LOADING



C-5A FWD. CARGO RAMP

C-5A AFT CARGO RAMP

Figure 2-30 C-5 Characteristics (Sheet 2 of 2)

open for roll-on/roll-off loading of vehicles. When interfacing with a cargo loader, the ramp is in the horizontal position.

Cargo Related Information

- In the logistics system configuration, the C-17 can accommodate two sticks (rows) of 9 each standard 463L pallets for a total of 18 pallets. Pallets are placed with the longer dimension (108") running the length of the aircraft.
- In the aerial delivery system configuration, the C-17 can accommodate a single stick of 11 standard 463L pallets down the center of the aircraft. Pallets are placed with the shorter dimension (88") running the length of the aircraft.
- Maximum freight capacity is approximately 172,200 lbs.
- Cargo compartment is equipped to accommodate general bulk and palletized cargo, vehicles, troops, paratroops or cargo rigged for airdrop.
- For additional information on cargo compartment envelope refer to Figure 2-31.

2.1.5.1.5 KC-10. The KC-10 Advanced Tanker Cargo Aircraft (ATCA) is a three engine low-winged aircraft which can function as both a tanker and a cargo freighter. Basically, a militarized version of the McDonnell Douglas DC-10-30, the KC-10 has been modified to include body bladder fuel cells in the lower cargo compartments, a boom operator's station, and an aerial refueling boom, a refueling receptacle and military avionics.

The primary mission of the KC-10 is to increase U.S. air mobility on a worldwide scale through long-range aerial refueling in support of general purpose as well as strategic airlift forces. In its tanker role, the KC-10 can fly 2000 miles, off-load more than 30,000 gallons of fuel to other aircraft and return to its base of origin. The cargo capability of the aircraft can be used to augment airlift forces by moving palletized cargo between widely separated locations.

C-17 CARGO COMPARTMENT ENVELOPE

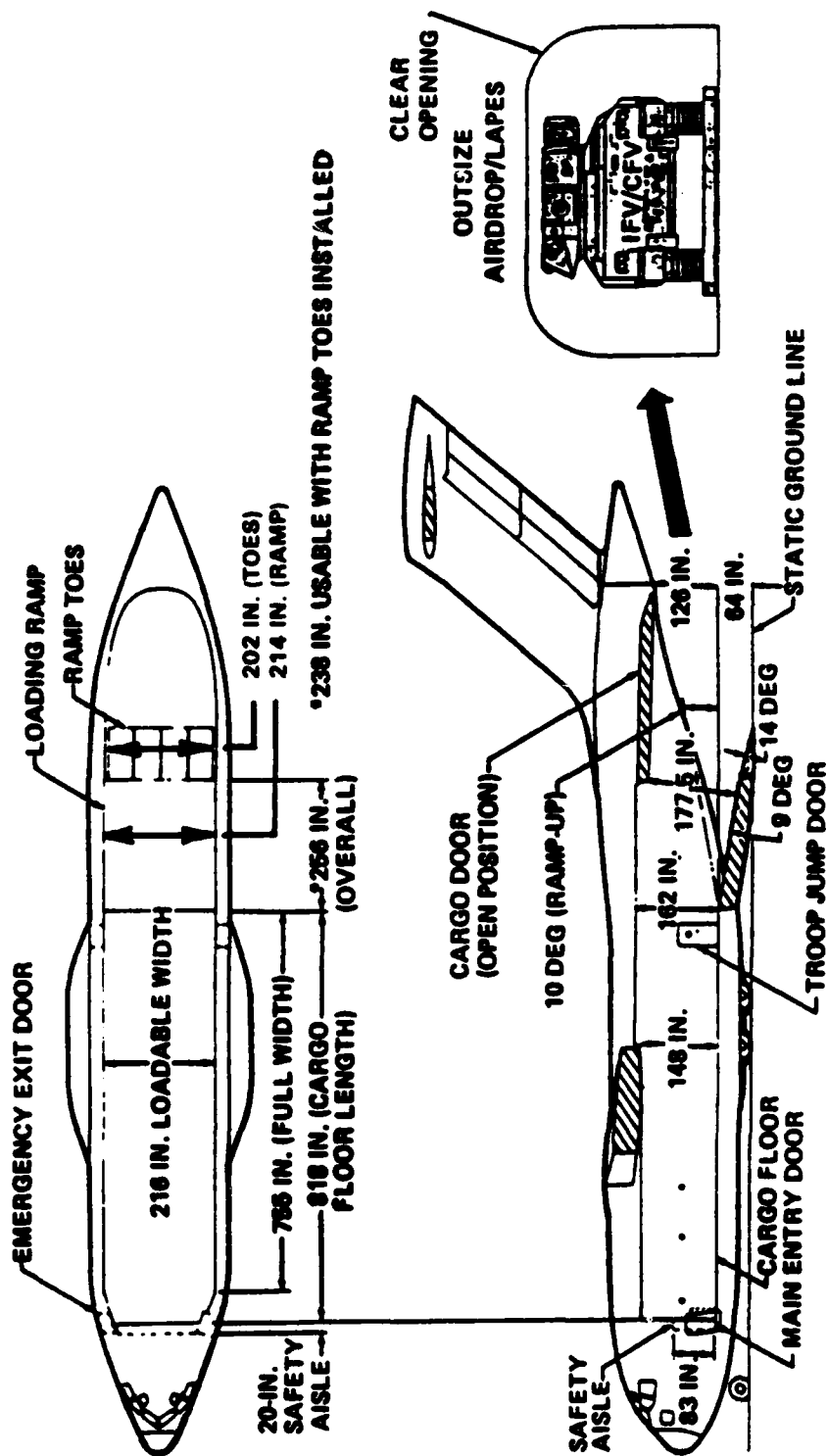


Figure 2-31 C-17 Characteristics (Sheet 1 of 2)

C-17
PALLETIZED CARGO CAPABILITY

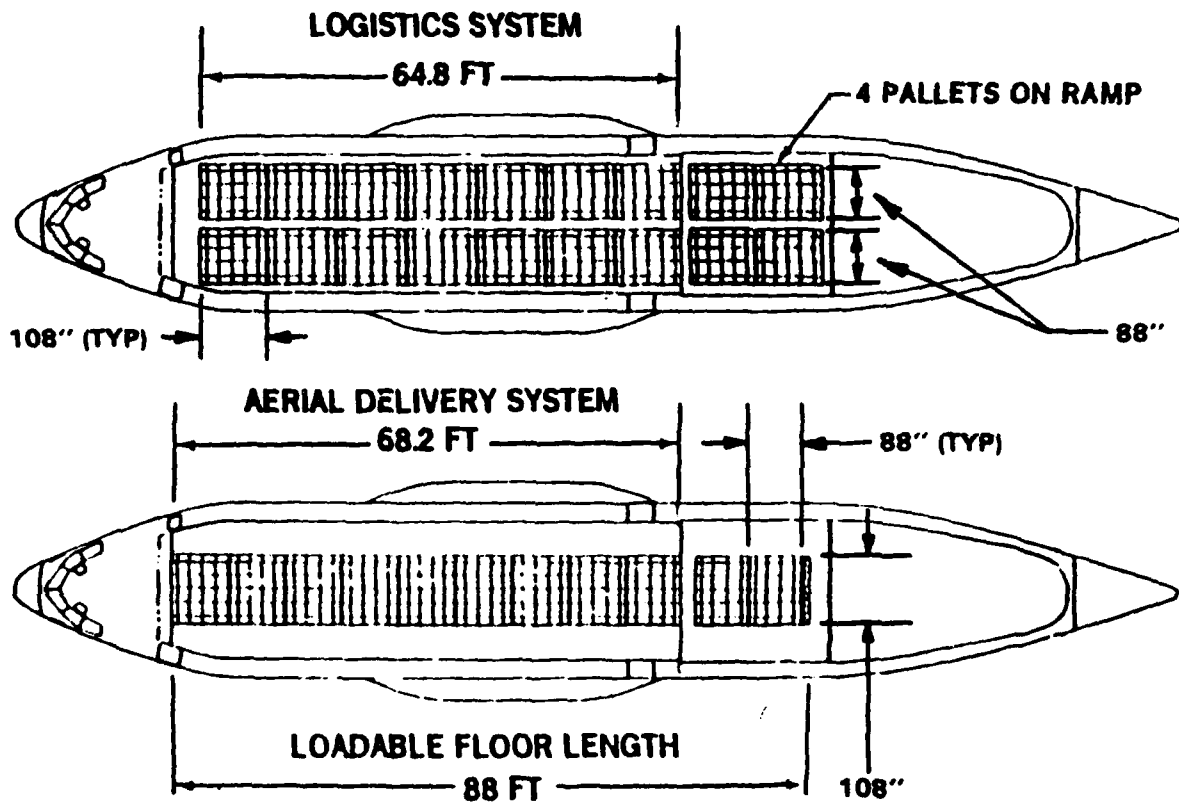


Figure 2-31 C-17 Characteristics (Sheet 2 of 2)

Cargo Related Information

- Can accommodate 27 standard 463L cargo pallets for a maximum cargo weight of 170,000 pounds.
- Cargo deck is also compatible with commercial pallets used in Civilian Cargo Aircraft.
- Nominal dimension from ground level to floor at cargo door is 15 feet, 9 inches
- Cargo door opening is 140 inches wide by 102 inches high.
- KC-10 will handle an 8 foot by 8 foot by 10 foot container. The 20 foot long container cannot be loaded, as it will not make the turn in the doorway.

2.1.5.1.6 Advanced Tactical Transporter (ATT). As noted in earlier sections, the Military Airlift Command and the Aeronautical Systems Division are currently investigating the requirements for the ATT. This aircraft is conceptualized to replace the C130 for tactical operations, with an advanced integral cargo handling system. Specifications for the ATT are not yet developed, but it is anticipated that at the time of initial operational capability of the ATT, the 463L system will still be intact and the ATL serving as the primary aircraft loader. As appropriate, continuing input from ASD should be made during development of the ATL, both to insure to the greatest degree that the ATL will have ATT capability and to insure that ATT development does not compromise the utility of the ATL.

2.1.5.2 Commercial Contract (CRAF). The Civil Reserve Air Fleet (CRAF) consists of a number of commercial passenger and freight haulers who have contracted with MAC to provide aircraft and operating personnel as the need arises. Since it is obvious that MAC will be required to load/off-load commercial aircraft during a contingency, these civilian aircraft must be

identified and evaluated for interface considerations with the military cargo loader. Aircraft currently comprising the CRAF system include: DC-8, DC-9, DC-10, L-100, L-188, B707, B727 and B747. The cargo related characteristics of these aircraft are explored in the following sections.

Note: Since this study is concerned with the cargo handling aspects of each aircraft, only freighters are considered unless otherwise noted.

2.1.5.2.1 DC-8. The DC-8 manufactured by McDonnell Douglas is a narrow body aircraft which can carry from 52,000 to 90,000 pounds of cargo. Variations depend on aircraft series, spacing requirements of the seats and contract requirements. In general, the DC-8-30 series and -50 series have 13 pallet positions; the DC-8-62CF has 14 pallet positions; and the so-called stretch DC-8-61F/63F/CF and 71CF/73F/73CF have 18 pallet positions. The lower lobes cannot accept loaded pallets because of door size limitation and the rounded contour of the floor. A main deck pallet subfloor is required for rolling stock.

For a representative DC-8 Cargo Loading Envelope, refer to Figure 2-32.

2.1.5.2.2 DC-9. The DC-9 manufactured by McDonnell Douglas is a narrow-body aircraft which can carry from 24,800 to 33,825 pounds of cargo. Variations depend on aircraft series, spacing requirements of the seats and contract requirements. In general, the DC-9-15F series has (6) 463L pallet positions and the DC-9-32F has (8) 463L pallet positions. The lower lobes cannot accept loaded pallets because of the door size limitation and the rounded contour of the floor.

For a representative DC-9 Cargo Loading Envelope, refer to Figure 2-33.

DC-8 MODEL 61F CARGO LOADING ENVELOPE

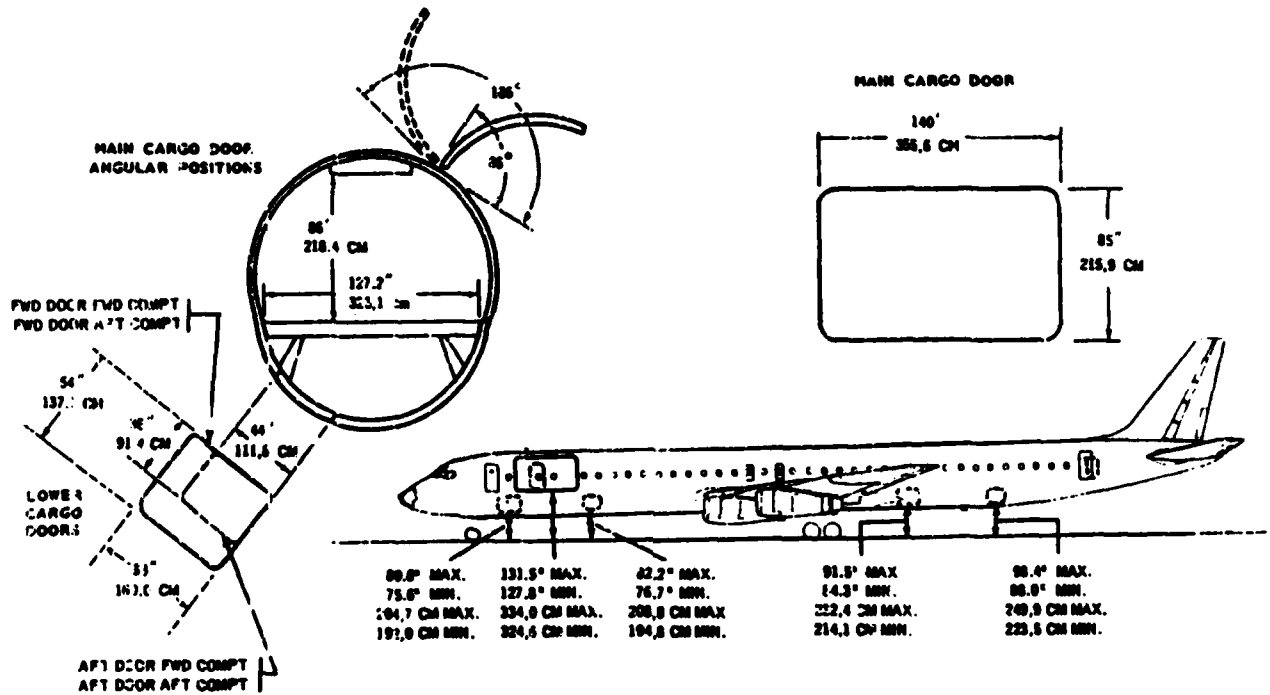


Figure 2-32 DC-8 Characteristics

CARGO LOADING ENVELOPE

DC-9 SERIES

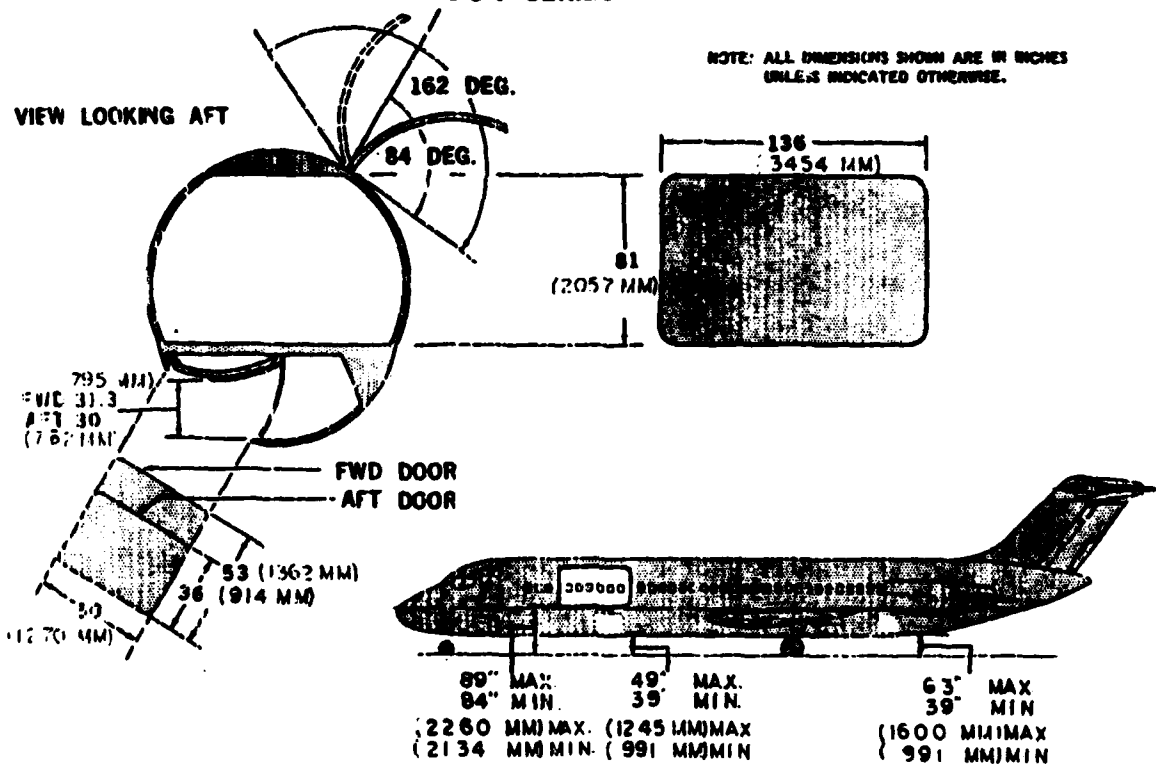


Figure 2-33 DC-9 Characteristics

The DC-10 has three lower lobe compartments: Forward Lower Lobe (FLL), Center Lower Lobe (CLL) and Aft Bulk Compartment (ABC). There is a wide variation in the length of these three compartments and in their access doors. The lower galley configuration is the most common.

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2-88

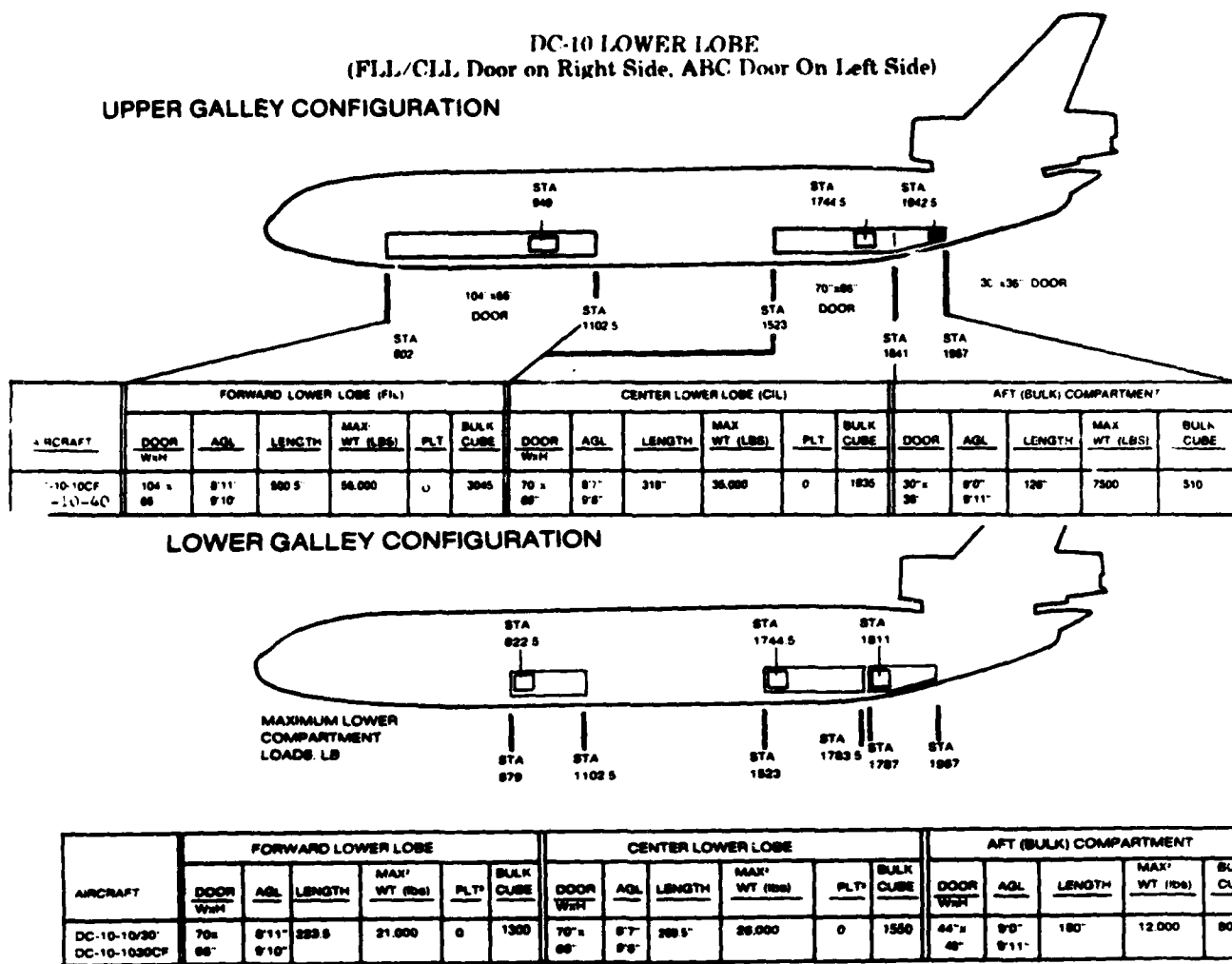


Figure 2-34 DC-10 Specifications (Sheet 2 of 2)

2.1.5.2.4 L-100-30. The Lockheed L-100-30 Hercules Air Freighter is a high wing, four-engine, turboprop aircraft. Basically a stretched C-130, this aircraft is used primarily as a commercial freighter. The cargo compartment is nominally 56 feet long by 120 inches wide by 108 inches high. The cargo floor is equipped with a 463L conveyor system, which consists of rollers, guide rails and locks. Palletized cargo may be loaded across the aft ramp door by K-loaders or forklifts with slave pallets.

Cargo Related Information:

- Maximum freight capacity is 51,110 pounds
- Floor height above ground = 41 inches
- Ramp opening is 120 inches wide by 78 inches high
- The L-100-30 is equipped with provisions to accommodate eight large cargo pallets (88 inches by 108 inches) including one pallet in the ramp position or sixteen small pallets (54 inches by 88 inches).

2.1.5.2.5 L-188. The Lockheed Electra (L-188) freighter is a short to medium range transport aircraft powered by four turboprop engines. Used primarily by Logair and the Alaskan Air Command, the L-188 carries palletized cargo which can be loaded through the fore and aft cargo compartments by use of K-loaders or forklifts with slave pallets.

Cargo Related Information:

- L-188 can accommodate 17 small pallets (54 inches by 88 inches) or (8) large pallets (88 inches by 108 inches) and one small pallet.
- Main cargo compartment is nominally 68 feet, 9 inches long by 119 inches wide by 87 inches high.
- Dimensions from ground level to forward main deck cargo door sill is 8 feet, 6 inches.
- Dimension from ground level to aft main deck cargo door sill is 9 feet, 2 inches.

- Forward main deck cargo door is 140 inches wide by 90 inches high (when aircraft has forward cargo door only) and 140 inches wide by 80 inches high when aircraft has forward and aft doors.
- Aft main deck cargo door is 142 inches wide by 80 inches high (when aircraft has aft cargo door only) and 98 inches wide by 80 inches high when aircraft has forward and aft doors.
- Cargo handling system is comprised of 463L compatible hardware including rollers, pallet locks and tiedowns.
- Lower cargo compartments. Two additional cargo compartments are contained in the lower fuselage section; a forward compartment (254 cubic feet, capacity 3,270 pounds) and an aft compartment (270 cubic feet, capacity 4,050 pounds). Total volume - 524 cubic feet.
- Forward and aft lower cargo doors are each 52 inches wide by 42 inches high.

2.1.5.2.6 B707. The Boeing 707 narrow body aircraft can carry 59,800 to 73,000 pounds of cargo. Variations depend upon aircraft series, individual aircraft configurations and contract requirements. The B707 Convertible (C) and Freighter (F) have (13) 463L pallet positions available. The lower compartments cannot accept loaded pallets due to door size restrictions and the rounded contour of the floor. For a main deck representation Cargo Loading Envelope refer to Figure 2-35.

2.1.5.2.7 B727-100C. The Boeing 727-100C is a medium range transport aircraft powered by three turbofan jet engines. This convertible cargo-passenger aircraft is identical to the 727-100, except for installation of heavier flooring and floor beams and a large cargo door. The cargo compartment is nominally 72 feet, 8 inches long by 11 feet, 8 inches wide by 7 feet, 2 inches high. Loading is through a forward cargo door with the cargo on pallets or in containers.

Cargo Related Information:

- 727-100C is equipped with provisions to accommodate 38,000 pounds of cargo on eight standard 463L pallets.
- Cargo door opening is 92 inches high by 134 inches wide.
- Cargo door sill height above ground is 10 feet, 6 inches.
- Maximum payload is 43,800 pounds.

2.1.5.2.8 B747. The Boeing 747 is a wide-body aircraft which can carry 180,000 pounds of cargo or more depending on series and individual aircraft configuration. Due to floor limitations, all military cargo must be palletized or on a palletized shored subfloor. The main deck of the 747 can be configured for a 33-37 pallet configuration depending on mix of load.

The lower lobe has three sections. The Forward Lower Lobe (FLL) can carry up to five military or commercial pallets. The Center Lower Lobe (CLL) can carry four military or commercial pallets. The Aft Bulk Compartment (ABC), separated by a removable curtain from the CLL, can carry 800 cubic feet of bulk cargo. All cargo must be palletized, put on a 463L pallet subfloor (except the aft bulk area which has its own subfloor) or containerized.

For B747 Cargo Loading data, refer to Figure 2-36.

2.1.5.3 Other Aircraft. Although not considered immediate members of the MAC family of cargo aircraft, there are numerous other aircraft which may be at certain strategic aerial ports and require servicing by the loader defined in this study.

Examples of such aircraft are: the C-160 Transall military transport, the G222 general purpose military transport, the C-23 Sherpa light duty freighter and the Airbus A300-600.

Cargo related characteristics of these aircraft are described in the following sections.



2.1.5.3.1 C-23. The C-23 Sherpa, manufactured by Short Brothers PLC of Northern Ireland is a short-haul all-freight version of the Shorts C-330 regional airliner. Operated by MAC and controlled by CINC-USAFE, the C-23 is primarily used to ferry high priority spares and complete aircraft engines. The C-23 is used in the European Distribution System Aircraft program (EDSA) and services at least 20 USAF bases in a system analogous with the civil air freight operation carried out by Federal Express in the U.S.

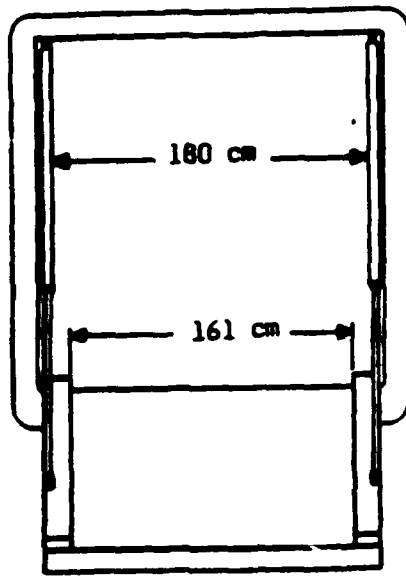
Cargo Related Information:

- Cabin is 6 feet, 6 inch square by 29 ft, 10 inches long with removable roller system.
- Loading is provided via a forward freight door (4.63 ft wide by 5.46 ft high) and a hydraulically operated full width rear ramp door.
- Nominal dimension from ground level to cargo floor at rear ramp is 39.4 inches.
- Maximum freight capacity is 7,000 pounds including four LD3 containers and engines the size of the F100 series.

For rear ramp door details, refer to Figure 2-37.

2.1.5.3.2 C-160. The Transall C-160 twin turboprop aircraft was developed to meet the specific needs of the Federal German and French Governments for a military transport capable of carrying troops, casualties, freight, supplies and vehicles. These aircraft can be equipped as flight refueling tanker/receivers and can operate from semi-prepared surfaces. The aircraft can accommodate 93 troops; 61-81 fully equipped paratroops; armored vehicles, tanks and trucks not exceeding 35,275 pounds total weight.

Loading is accomplished through a front port side cargo door and through a hydraulically operated rear loading ramp. Loads which cannot be driven in can be taken on board by a winch and system of roller conveyors. Individual loads up to 17,000 pounds can be airdropped.



SECTION A-A

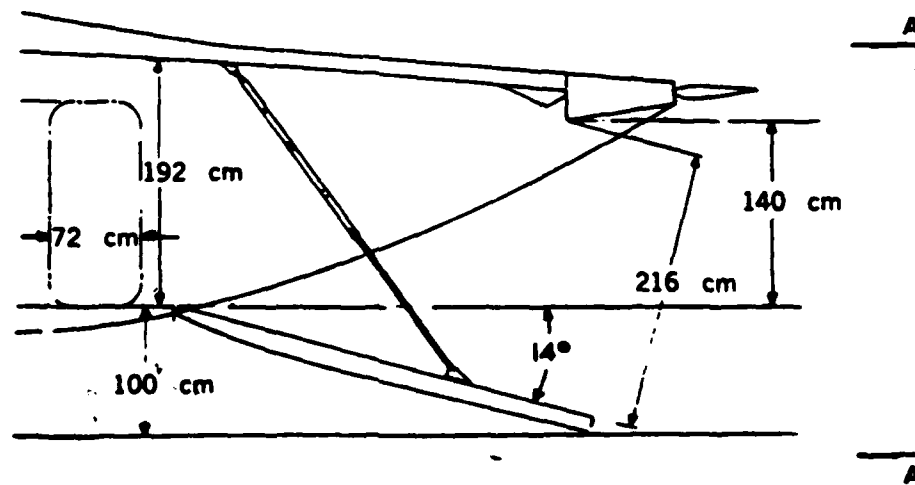


Figure 2-37 C-23 Sherpa

Cargo Related Characteristics:

- Maximum payload is 35,275 pounds.
- Dimension from ground level to cargo floor with rear ramp horizontal is 39.4 inches (minimum), 58.3 inches (maximum).
- Nominal dimensions of cargo opening at rear ramp is 128.7 inches wide by 106 inches high.
- Angle of rear cargo ramp with ground level when fully lowered is 15 degrees.

2.1.5.3.3 G222. The G222 Aeritalia is a twin prop, general purpose military transport with a maximum cargo payload of 19,840 pounds. Used primarily by the Italian Air Force, this aircraft serves as a cargo transport as well as troop and aeromedical carrier. Under NATO agreement, the USAF is required to provide cargo load/off-load support for the G222 at those bases where interfaces are necessary. Loading is accomplished through a hydraulically operated rear loading ramp and upward opening door in underside of upswept rear fuselage, which can be opened in flight for airdrop operations. The aircraft is equipped with provisions to accept standard 463L pallets.

Cargo Related Information

- Main cabin is 28 feet, 1-3/4 inches long by 8 feet, 1/2 inch wide by 7 feet, 9-1/2 inches high.
- Rear cargo door/ramp is 8 feet, 1/2 inch wide by 7 feet, 4-1/2 inches high.
- In the cargo version, 5 pallets of up to 2,205 pounds each can be air dropped from rear opening, or a single pallet of up to 11,023 pounds.

2.1.5.3.4 Airbus A300-600. The Airbus A300-600 is a twin-engined large capacity wide-bodied medium range transport manufactured by Airbus Industries. Although, to our knowledge, there is no scheduled servicing of this aircraft by the future cargo loader, it seems reasonable to assume, that, in a

contingency, this aircraft would be part of the NATO fleet and therefore has been included in the list of other aircraft to be serviced.

The A300-600 has many variations depending on aircraft series, spacing requirements of seats and mixed passenger/cargo configuration. For simplicity the cargo loading characteristics identified are for the A300F freighter.

Cargo Related Information:

- Maximum freight capacity is 110,782 pounds.
- The aircraft is equipped with provisions to accept a maximum of 21 standard 463L pallets on the upper deck.
- Loading system consists of ball mats, roller tracks and electrical drive units.
- Upper deck cargo door (forward port) is 8 feet, 5-1/4 inches high by 11 feet, 9 inches wide. Height from ground to cargo door sill is 16 feet, 1 inch.
- Under floor baggage and cargo holds are fore and aft of wings with doors on starboard side.
- Forward underfloor cargo hold is 34 feet, 9-1/2 inches long. Rear underfloor cargo hold is 26 feet, 1 inch long. Bulk baggage extreme rear hold is 11 feet, 2 inches long. Maximum height is 5 feet, 9 inches, maximum width is 13 feet-9 1/4 inches.
- Underfloor cargo door sizes and sill heights are:
 - Underfloor Cargo Door (Forward) 5 feet-7 1/2 inches high by 8 feet, 10 inches wide by 10 feet, 1 inch sill height.
 - Underfloor Cargo Door (Rear) 5 feet, 7-1/2 inches high by 5 feet, 11-1/4 inches wide by 11 feet, 2-1/4 inches sill height
 - Underfloor Cargo Door (Extreme Rear) 3 feet, 1 inch high by 3 feet, 1 inch wide by 11 feet, 8 inches sill height.

2.1.6 Aerial Ports/Terminals

The types of aerial ports established, or identified for potential use in a wartime contingency, are based to a large extent on the types of airlift

operations which they must support and sustain. As discussed above in paragraph 2.1.1.1, there are two airlift functions: strategic and tactical.

The predominant characteristic of these airlift operations are the aircraft used. Inter-theatre airlift is by the large, inter-continental aircraft, intra-theatre is by the short-range, lower payload C-130. The C-17 will eventually enhance and increase both the inter and intra-theatre capacity.

It follows that aerial ports are established, or identified for contingencies, (1), on the basis of airfield capability (runway; taxiway, parking area, load bearing capability) and (2), on the basis of cargo handling and maintenance and support capabilities. For the purpose of contingency planning, the USAF has identified and cataloged all known airfields in the free world. See Table 2-6. In addition to USAF permanently established and/or controlled air bases, these airfields are potentially those which can support contingency operations for strategic and tactical airlift. Cargo handling and maintenance support capabilities of these contingency aerial ports will vary from one location to another, and in most instances, will require equipment to be prepositioned or air-transported. Generally accepted characteristics of these varied aerial ports fall into four general categories.

1. Main Operating Base (MOB): MOBs are permanently established aerial ports, suitably equipped for airlift operations for wartime use. MOBs serve as APOE and APOD for strategic airlift. Runways are unrestricted for large intercontinental aircraft. The airfreight section (terminal) is mechanized and capable of handling all cargos included in the total airlift service. This includes a full complement of mobile MHE as described in paragraph 2.1.4, plus fixed equipment such as highline and omni-directional roller docks designed for pallet sorting and staging areas for K-loaders. Terrain is typically paved or hard-pan surface with minimal grade (3%) and no obstructions.

Table 2-6 Airfield Summary

RUNWAY LENGTH X WIDTH	AFRICA	CENTRAL EUROPE	SOUTH AMERICA	MIDDLE EAST	FREE WORLD LESS U.S.
5000 X 150	201	56	157	144	1,576
5000 X 90	641	247	535	393	3,488
4000 X 90	1,059	294	1,182	480	5,640
3000 X 90	1,902	436	2,837	586	9,887
2000 X 90	2,702	710	4,855	640	15,165

2. **Deployment Operating Base (DOB):** DOBs are similar to MOBs in size and physical facilities. They can be permanently established but are not typically used for airlift operations in peacetime. Consequently, air terminal capability is limited at best and MHE must be provided by air transport from an MOB or prepositioned. Terrain should be expected to be as that of an MOB.
3. **Forward Operating Base (FOB):** An FOB is an airfield established for non-airlift operations. Airfreight capabilities are limited to the 25K loader, TAC loader and 10K adverse terrain forklift. Paved runways, taxiways, and parking areas are restricted and limited in size, requiring off-highway, unpaved terrain negotiation by MHE. The FOB may be a primary onload base for intra-theatre airlift operations.
4. **Small Austere Airfield (SAAF):** SAAFs have a paved or semi-prepared (compacted gravel, sand, etc.) runway and limited taxiways and parking areas. The SAAF will be the final off-load base for intra-theatre airlift. Terrain in the immediate vicinity of the SAAF is undeveloped requiring the most severe terrain capability for MHE, which is normally limited to the 10K forklift and TAC loader.

Runway length and load bearing capacity of the FOB and SAAF will limit airlift operations to the C-130, C-17 and ATT. MOBs and DOBs will handle the total airlift operations including the C-130, ATT, C-141, C-5, C-17, KC-10 and CRAF.

2.2 OPERATIONAL ENVIRONMENT

MAC currently operates almost 1,000 aircraft at more than 325 locations in 26 countries. For contingency planning, they have identified and cataloged all known airfields in the world. Considering these thousands of locations scattered over the globe, it is easy to see that the range of climatic conditions range from tropic to arctic and everything in between.

The Aircraft Transporter Loader (ATL) will see worldwide usage and consequently will be subjected to the climatic and environmental conditions, both natural and induced as indicated by the wide range of locations.

The natural environmental conditions are fairly self-explanatory and include such anticipated elements as: wind, rain, cold, snow, sleet, heat, fungus, sand, and dust.

The induced conditions are more clearly associated with the operational needs and interfaces of a military airfield environment. Elements to be considered include: terrain, system contamination, electromagnetic interference and concurrent refueling of aircraft (explosive atmosphere conditions).

Still another set of individual conditions which must be considered are the effects from a post nuclear, biological, chemical (NBC) environment on the loader, should a major contingency occur.

In the following sections, these and other environmental influences are explored in greater detail.

2.2.1 Airfield Terrain

With the thousands of airfields available to MAC throughout the world, it is not feasible in a study of this magnitude to evaluate the individual topography of each one. However, enough is known in general terms to define the characteristics of the airstrip and surrounding service and access areas.

Taxiways and hardstands are hard, flat (within 3% grade) and capable of supporting the heavy loads imposed by aircraft and support equipment. Since cargo must be transported to and from the aircraft and terminal, or marshalling area, it is necessary that these access ways be hard, level and improved, with minor obstructions.

In the case of Small Austere Airfields (SAAF), it is most likely that the taxiways and hardstands will also be hard and flat. However, the transport of cargo to and from the aircraft and marshalling area may be on unimproved roads or off highway - hence, the need for the 25K tactical loader.

2.2.2 Weather/Environmental Conditions

Kadena AB, Japan, where MBE is stored outside, experiences a severe corrosion environment due to high humidity and salt air/salt spray. Clark AB, Philippines has experienced hydraulic seal problems in MBE due to high moisture and temperature variations. Osan AB, Korea, where MBE is stored outside, experiences cold weather starting and icing problems during the winter months; and Elmendorf AFB, Alaska is faced with the maintenance and operational problems associated with arctic or near arctic conditions.

The requirement that ground support equipment be designed to operate in varying climatic/environmental conditions is not an unusual one, and indeed, is to be expected in order to perform the military mission.

In evaluating the design parameters for equipment of this type, it is often prohibitive in cost or technically impossible to design equipment to operate anywhere in the world under the most stringent conditions ever recorded. For this reason, the military normally specifies equipment designed to operate under environmental stresses, which more closely reflect the reasonable expectation of operations.

A helpful guide to uniform climatic design criteria for military equipment intended for worldwide usage is MIL-STD-210 entitled "Military standard Climatic Extremes for Military Equipment".

2.2.3 System Contaminants

Contamination of hydraulic fuel and air systems may be caused by natural or induced environmental conditions. The primary contributors to system contamination are water or moisture, and sand or dust. Sand and dust are terms used to designate small particles of matter, usually of mineral origin. A distinction is often made between sand and dust on the basis of size (dust particles are smaller), but there are no generally accepted specific limits for the two kinds of particles. However, for most military applications, it is important to distinguish between the effects of the smaller particles (dust) and the larger particles (sand) because of their primary effects on equipment. Airborne dust is primarily deleterious because of its penetration and subsequent possible damage; where airborne sand is primarily deleterious because of its erosive and abrasive effects on equipment.

Tests have shown that heaviest particle concentrations are found near helicopters hovering over dry, loose surfaces. Secondary concentrations are found near ground vehicles operating on unpaved surfaces, including many roads. Lesser concentrations are associated with natural dust storms, although the real extent of such storms may be substantial. Almost no large world areas are exempt from sand and dust problems, at least during some part of the year.

When the USAF went into Granada in the Fall of 1983, the newly constructed airstrip with its semi-finished surface was coated with a fine layer of abrasive dust. As aircraft and helicopters took off and landed, the dust

coated all of the equipment until the aircraft loaders were inoperable due to clogged air filters. It was not until the filters were cleaned or replaced that the equipment was able to be put back into operation.

Excessive moisture in a hydraulic system can lead to premature failure of pumps, valves and seals. Moisture in a fuel system can result in erratic operation, cause permanent damage and render the engine inoperable.

The two main causes of moisture in a system are leakage and condensation. Leakage is minimized by proper system design which includes locating vents, filler caps, etc., so that they are protected from rain and other external moisture sources during storage and operation.

Equipment which is stored in hot, humid climates must be adequately ventilated in order to minimize build-up of condensation. Fuel tanks should be kept full and coverings should be removed during dry periods to aid in drying out components.

2.2.4 Nuclear, Biological, and Chemical (NBC) Environment

Future battles will be waged in an NBC environment. This is evidenced by the increasing proliferations of nuclear, chemical and biological (NBC) weapons in conjunction with the apparent permissive attitude of the Warsaw Pact countries regarding the employment of these type weapons. The lethality of NBC weapons can be categorized in two major areas:

- At the vicinity of weapon use where high lethality is imparted to the unprepared personnel.
- In surrounding areas, where the atmosphere is polluted with hazardous contamination; generally down-wind.

In a battlefield where NBC weapons are used, the deployment complexity of troops and weapons will make it impossible to avoid contaminated areas during

tactical operation, and to a limited extent, strategic operations. This need to operate a system in an NBC environment without significant degradation in performance imposes certain design requirements. These requirements are manageable and affordable within acceptable limits. However, to be cost effective, these constraints must be addressed at the initiation of the design.

Of all the three threats mentioned above, the nuclear environment has serious impact on the equipment. Nuclear and chemical are more likely to be used and are a serious threat to the crew members.

2.2.4.1 Nuclear Survivability. Nuclear Survivability is the capability of a system to perform its defined functions after exposure to specified levels of nuclear weapons effects (EMP, blast, thermal, and initial radiation effects). The criteria for nuclear survivability are those specified levels of nuclear weapons effects which a given system must survive. The criteria depend on the system itself, its location on the battlefield, the yield of nuclear weapons likely to be employed near its location, the relationship of the operating personnel to the equipment, and the mission of the unit using the system.

The ability of equipment to operate in a nuclear environment imposes stringent requirements on the equipment design. The environment resulting from a thermo nuclear explosion will comprise of blast, ground shock, debris and dust. Thermal effects and several type of radiation effects threaten structures, materials, and electronic equipment. The most susceptible material under this environment is electronic systems. The specific nuclear environment and corresponding threat levels will depend upon the type of nuclear detonation, namely high altitude burst or tactical near surface burst. In both types of detonation intense Electromagnetic Pulse Energy (EMP) is generated which could seriously affect the electronic equipment.

The intense transient electromagnetic field generated by the nuclear detonation can induce high levels of EMP energy into electronic equipment. The inducement mechanism can be classified into three categories.

1. Diffusion through walls and enclosures.
2. Coupled into system via cables and antennas.
3. Entrance through windows, door openings, seams, intake and exhaust ports, displays and switches.

EMP can induce permanent or temporary damage or both to the electronic system and the resulting malfunction could be critical depending upon their impact against the equipment of performance.

The basic approach in designing the equipment for EMP is the same as that used against EMC, RFI, or lightning. These protective methods and techniques are generally practiced and most of the designers are well aware of it. New techniques and design methods to protect against specific frequency spectrum and energy levels are constantly being updated. The following paragraphs describe the various constraints that should be addressed during the design phase. The considerations should be translated as a part of requirements.

Threat:

Diffusion through metal structures

Protection:

- Provide solid enclosures as much as possible
- Provide metal gaskets
- Provide shielded cables

Threat:

Penetration through antennas, exterior cables

Protection:

- Provide grounding techniques
- Provide filtering

- Provide limitless, transient suppression
- Provide shields for cables and connectors

Threat:

Entrance through doors, windows, and holes

Protection:

- Provide metal gaskets, fully welded seams
- Provide honeycomb, perforated metal sheets to the large openings
- Provide see through wire mesh screen for small holes

2.2.4.2 Crew Protection. The most effective way of dealing with the NBC contamination problem is a multiphase approach. The crew must be made aware of the presence of contamination. Adequate personal protective measures must be taken; and also appropriate decontamination of exterior and interior vehicle surfaces, equipment and personnel must be accomplished quickly and completely when and where required. It is also important that the measures taken to protect the crew should not encumber them in any way and to an extent that compromise the system effectiveness. The following paragraphs discuss the requirements dictated by the NBC environment.

Awareness of the presence of the contamination:

- The crew members shall be alerted by the commander the presence of the threat so that crew members can don protective clothing or equip themselves with other safeguards.

Crew Protection Equipment:

- The crew should have a protective gear especially when they have to operate the vehicle in the area of suspected contamination. This gear includes a hood, gloves, boots and over garment. Each crew shall have a ventilation face mask. This has the advantage of minimizing the heat stress and supply of filtered air. This system should have a flexible tube feature which would allow the crew to have limited travel outside the vehicle.

Vehicle Design:

- The design of the vehicle shall be such that it should provide protection against contamination, unencumbered, unstressed by heat and against abnormal workloads.
 - The interior and exterior surface of the vehicle must be designed to facilitate rapid scrub down with slurry of decontaminant.
 - The vehicle must not incorporate materials which absorb chemical agents. Some paints, plastic and man made material which have this property should be avoided in the system design.
 - The surfaces should be smooth without crevices, and with minimum interior corners where chemical and biological agents can collect.
 - Complex components such as electronics should be tightly sealed.
 - The materials used in the manufacturing should not be degraded or react to decontamination fluid.

2.3 SYSTEM CONSTRAINTS

There are constraints within the overall air cargo system, which will have an impact on the characteristics and composition of elements of the systems. These constraints can be limiting factors in the design of an element of the system or are pre-established conditions, which must be satisfied as part of, or coincident with, the mission performance.

These constraints originate from established policy and procedures, experience, prior analysis and established physical limitations or conditions. Early identification and input of these constraints and their potential impact on the system is essential in deriving and developing the system or an element of the system, namely the ATL.

If we were to put this exercise in the right perspective, the ATL is a system element, which will be derived or developed to function within the established military air cargo handling system. The system constraints are then fixed or established by precedence. Some are unalterable and serve as limiting factors in developing the ATL. The physical characteristics of other system elements are examples of fixed constraints. The aircraft systems, cargo types, MHE and air terminal facilities are fixed and established assets with which the ATL must physically interface. AFOSH Standard 127-66 is an established policy stating the safety conditions and procedures to which the operation of the ATL must comply.

The requirement of air transportability of the ATL has the potential for the most severe physical limitations. The airliftable payload, cargo compartment floor load capacity and ramp negotiation requirements of the candidate aircraft have limitations which impact the unladen weight of the ATL and other design characteristics such as wheel base, axle spacing, axle load and tire loads and ground clearance.

Engineering speciality efforts, such as integrated logistics support (ILS), human factors engineering (HFE), and reliability, availability and maintainability engineering (RAM) are other input factors, which will impact the development of the ATL. These speciality engineering efforts are life-cycle management considerations and should be included at the time of program initiation.

2.3.1 System Equipment Interfaces

Performance capabilities and configuration of the ATL are largely affected by the established configurations of the cargo and the interface requirements between the ATL and the aircraft, the MHE and the terminal cargo

handling facilities. Some of these constraints are apparent in the descriptions of these system elements in Sections 2.1.3, 2.1.4, 2.1.5 and 2.1.6. These constraints are further outlined and detailed in the following sections.

2.3.1.1 Aircraft Systems. All of the military and CRAF aircraft have cargo compartments with roller-conveyor systems for acceptance and restraint of unitized cargo. These conveyor systems have the singular feature that cargo enters or exits the aircraft cargo compartment by horizontal and unidirectional transfer to or from the roller-conveyor system. This feature limits, if not dictates, the means by which cargo is loaded/unloaded, i.e., onto or off-of a horizontal surface at the same level as the aircraft cargo floor.

The variety of aircraft used in the system include as many cargo doors or cargo ramps. These cargo openings are one of the most critical interfaces for the ATL. Constraints peculiar to this interface will impact and limit the design and performance requirements of the ATL.

1. Deck Sill Height:

The range of heights which must be reached by the ATL deck is from a minimum of 39 inches (for the C130 E&H) to a maximum of 18 ft., 1 inch (B747 main deck). This range covers all of the main and lower decks of all MHE and CRAF aircraft.

2. Cargo Door/Ramp Access:

Access to the lower lobe cargo doors of wide-bodied aircraft is obstructed by the fuselage curvature (See Figure 2-38). The outward projection of the fuselage at the main deck cargo doors is somewhat reduced on the narrow-bodied and wide-bodied aircraft. The fuselage curvature and cargo door opening is different for each aircraft and

each must be considered for an optimal design of the ATL at this critical interface.

The ramp opening of the C-130 and C-141B have similar limitations. Figure 2-39 illustrates the potential overhead interference problem caused by the low profile of the C-130 aft fuselage. It is also the narrowest of the MAC aircraft, 120 inches, (See Figure 2-28).

The ramp opening of the C-141B is configured differently, (See Figure 2-29). Although the petal doors open to a 203 inches width (at the ramp level), there is an overhead limitation caused by the inward curvature of the petal door at the top, near the door hinge.

The C-17 has the same type of ramp opening as the C-130. With ramp toes used with the loading ramp, it appears that adequate clearance of the aft fuselage is provided, (See Figure 2-40). When loading directly to the ramp without the toes, overhead clearance between the cab and aft fuselage is minimized, when the loader is aligned with the port side logistics stick.

3. Ground Maneuvering Clearance

Maneuvering of the ATL for positioning at aircraft cargo doors/ramps is unrestricted for all of the considered aircraft, except for the B-747 and DC-10. The main deck side cargo door on the B-747 is located on the fuselage behind the port-side wing (See Figure 2-41). The center lower lobe door (not shown) is located at approximately the same location (between Sta 1810 and Sta 1920) on the starboard side of the fuselage. Overhead clearance for a straight-in approach or maneuvering the loader is limited to 159 inches (minimum).

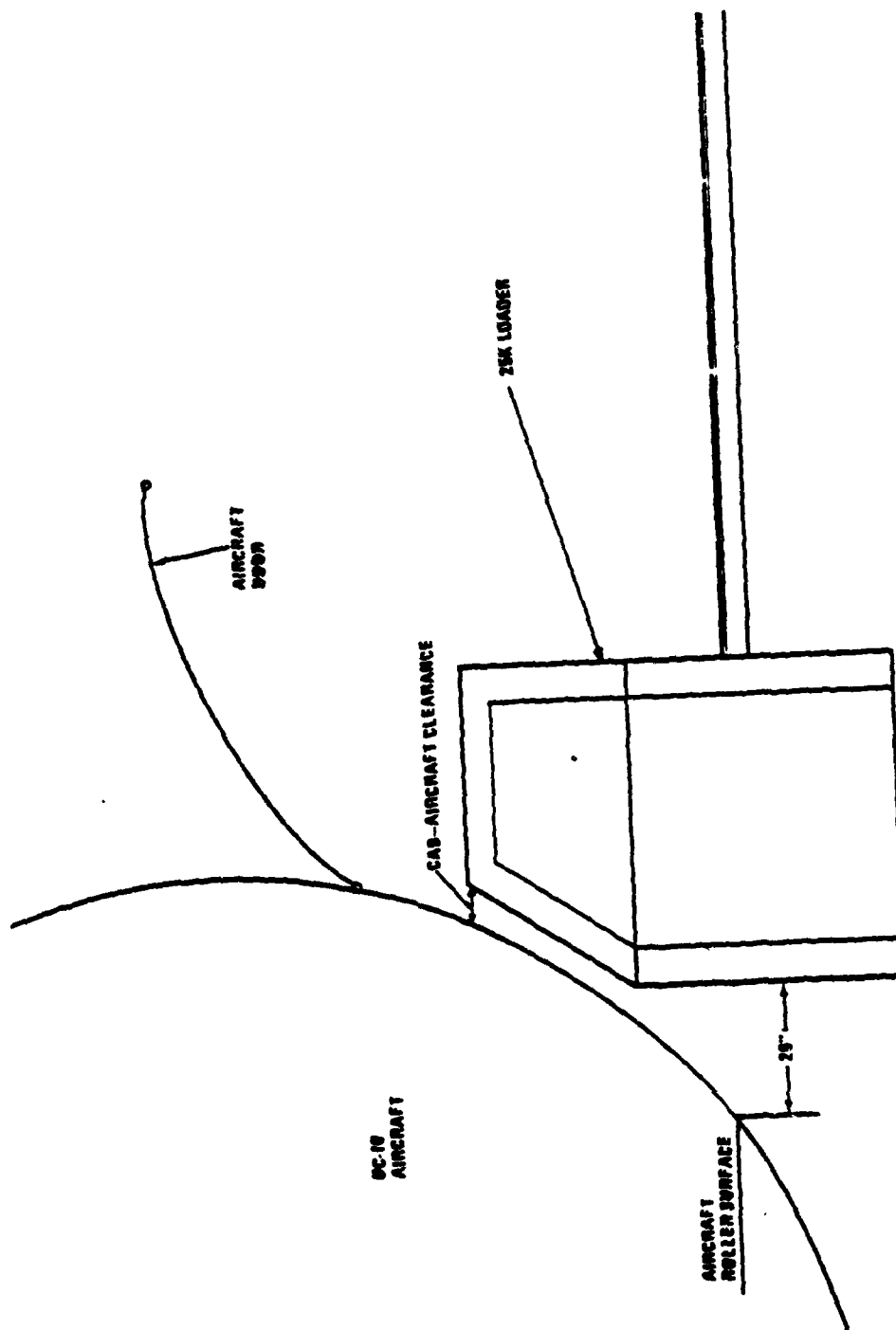


Figure 2-38 Fuselage Curvature at Lower Lobe Cargo Door

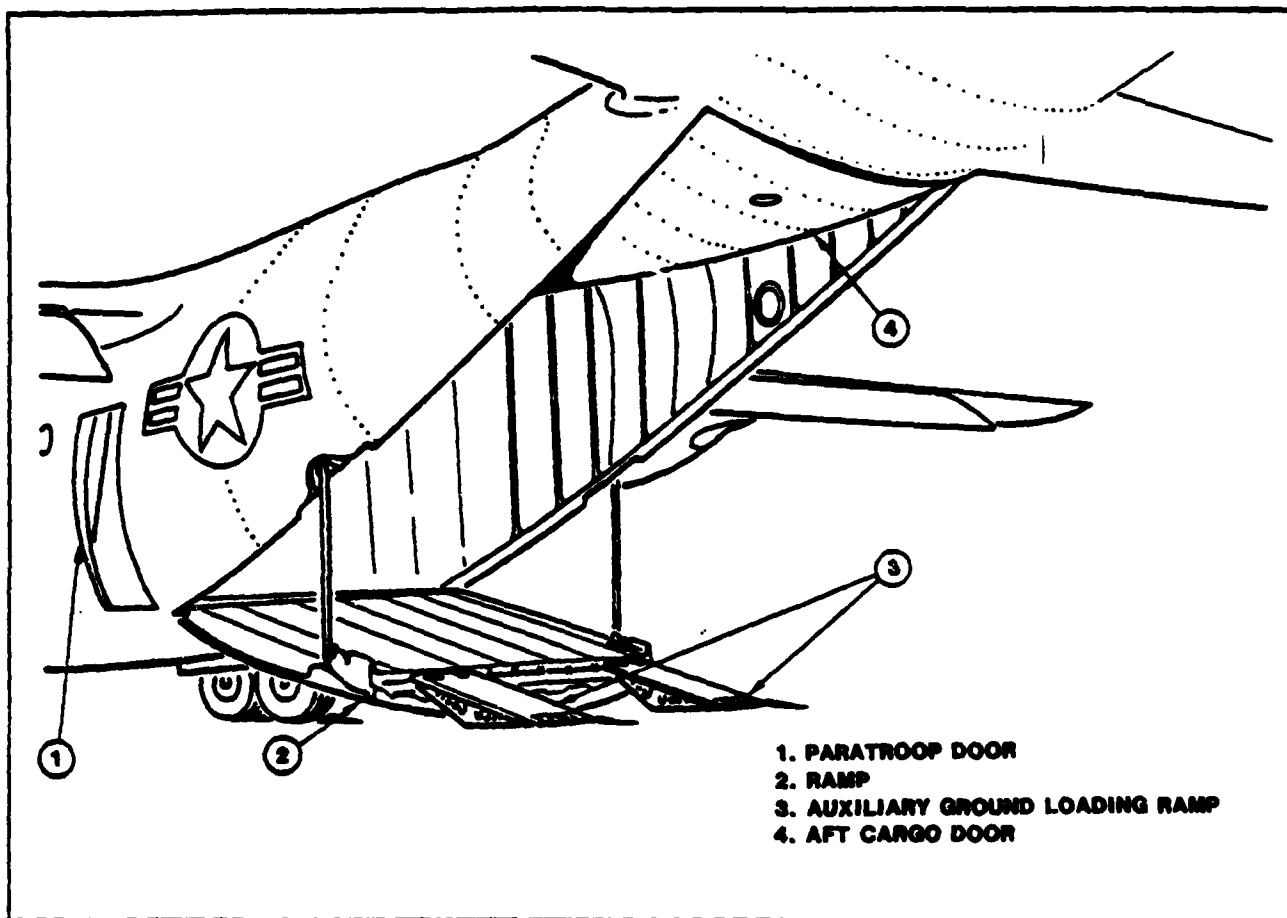


**Figure 2-39 C130 Aft Fuselage &
Ramp Opening**

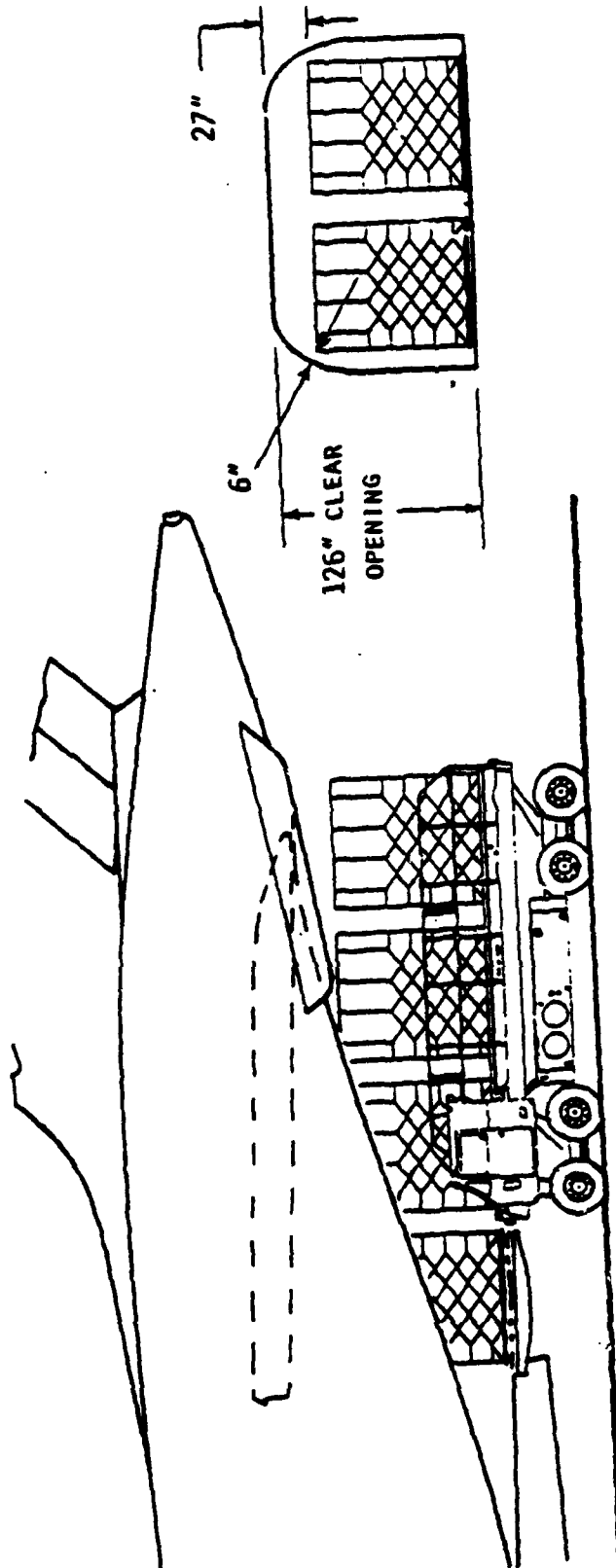
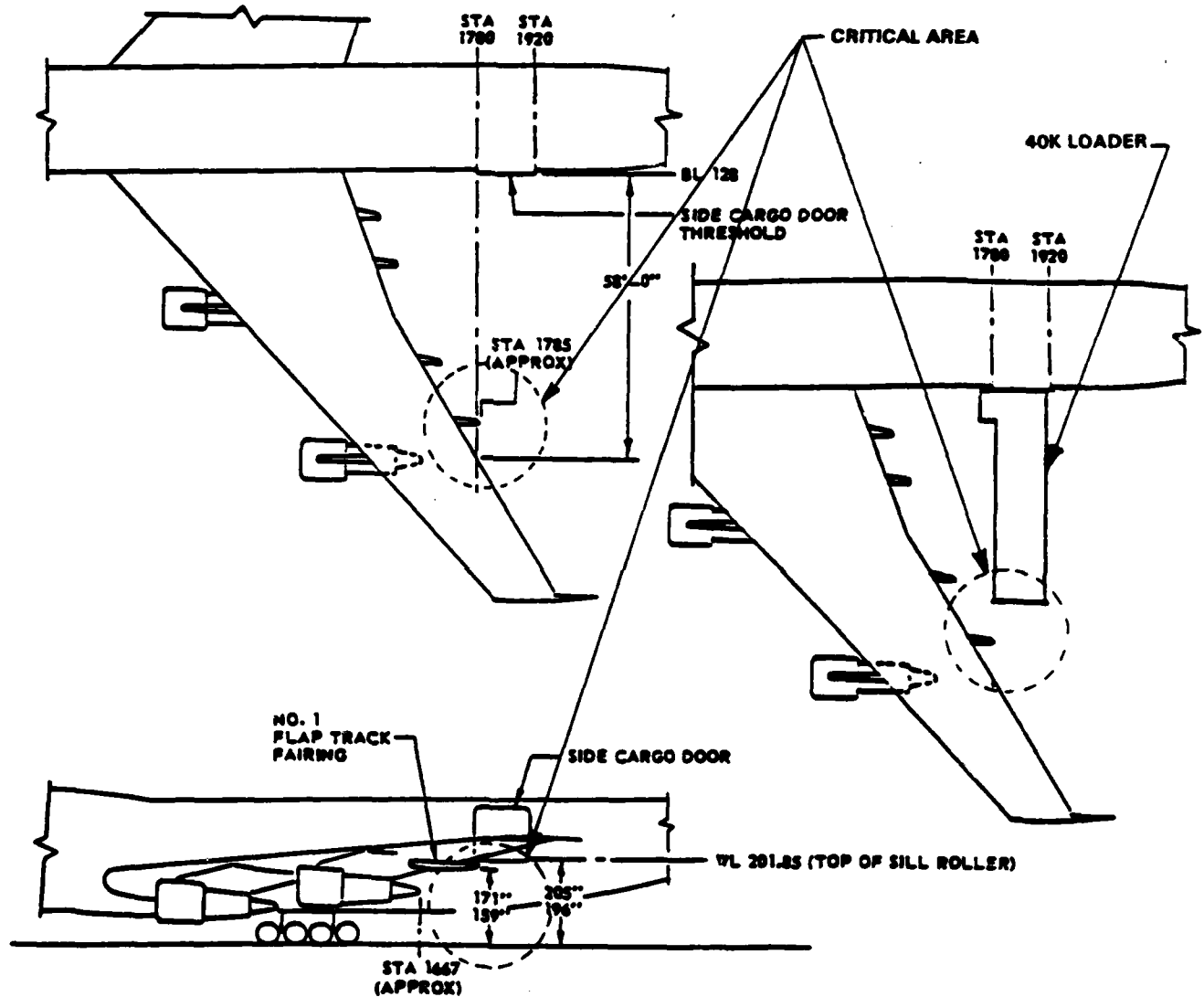


Figure 2-40 C17 Pallet Loading

MAIN DECK SIDE CARGO DOOR DOOR AREA CLEARANCES



THE ABOVE DRAWINGS PROVIDE CLEARANCES FOR DETERMINING EQUIPMENT ACCESSIBILITY FOR SIDE DOOR OPERATION. VERTICAL CLEARANCES ARE SUBJECT TO AIRCRAFT LOAD.

Figure 2-41 B747 Cargo Door Area Clearances

The DC-10 has minimal clearance for a loader at both the forward (FLL) and center lower lobe (CLL) doors (See Figure 2-42(1) & 2-42(2)). Overhead clearance of the starboard wing is limited to 170 inches. As can be noted in Figure 2-42(1), the right rear deck of the 40K loader is under the aircraft wing, when positioned at the CLL door. Cargo must be placed forward on the deck to avoid striking the wing. At the FLL door position, minimum clearance (approximately 2 ft.) is provided between the starboard side aircraft engine and the 40K loader.

2.3.1.2 Cargo Types. The ULD's described in paragraph 2.1.3 have three common characteristics:

- The ULD's are structurally designed to be conveyed and supported on a roller conveyor system.
- The ULD's are dimensionally designed to fit within a specified roller/restraint system for both vertical, lateral and longitudinal restraint.
- The ULD's are structurally designed for load capacities which are within the payload limits of the systems air and surface transport vehicles.

It follows then, that the performance capabilities of the ATL will be based on these ULD characteristics and they translate into the following constraints and limitations/capability.

- **Payload Capacity:** The maximum single load weight is the planned U.S. Army 60,000 lb., 32 foot airdrop platform.
- **Payload Size:** Maximum width for all ULD's is the 108 inches (pallet, platform and adapter). Maximum length is 40 feet for ISO containers.
- **Load Bearing Capacity:** All ULD's are supported and conveyed from the underside. Contact loads and load support distribution of a supporting conveyor must be based on the load bearing capability of the ULD interface surface.

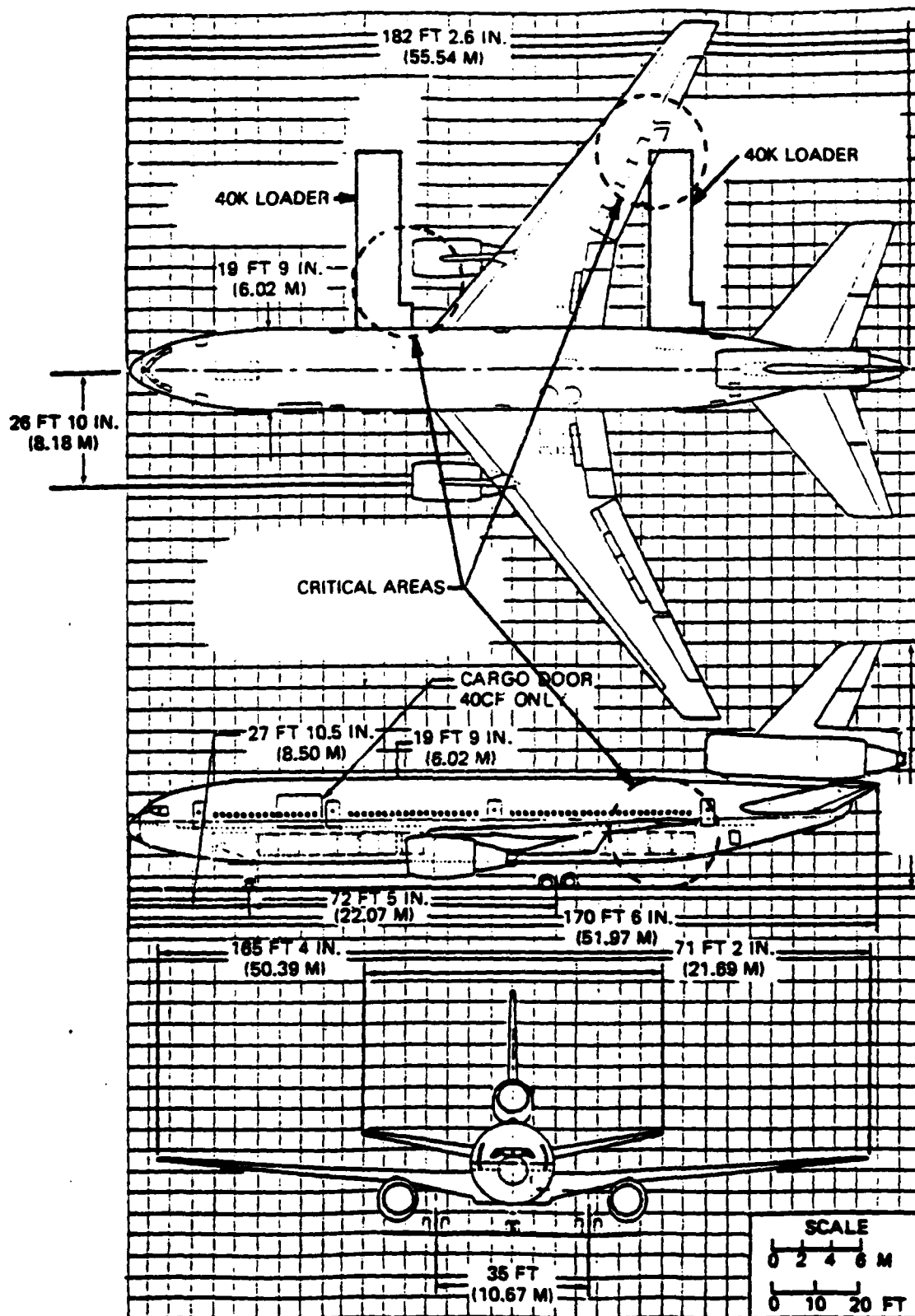
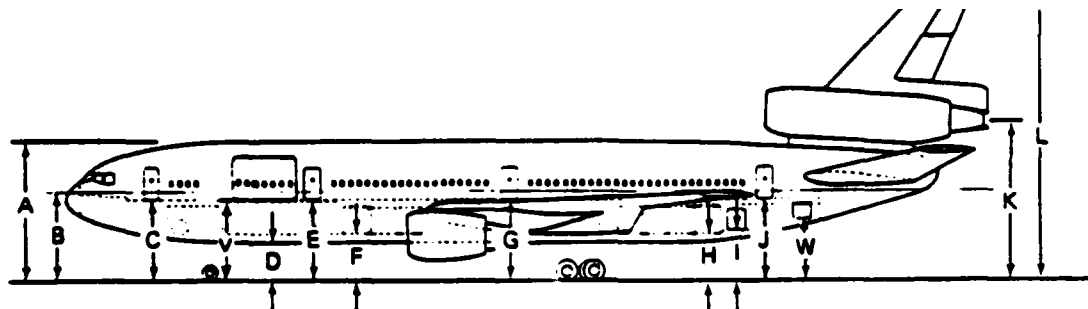
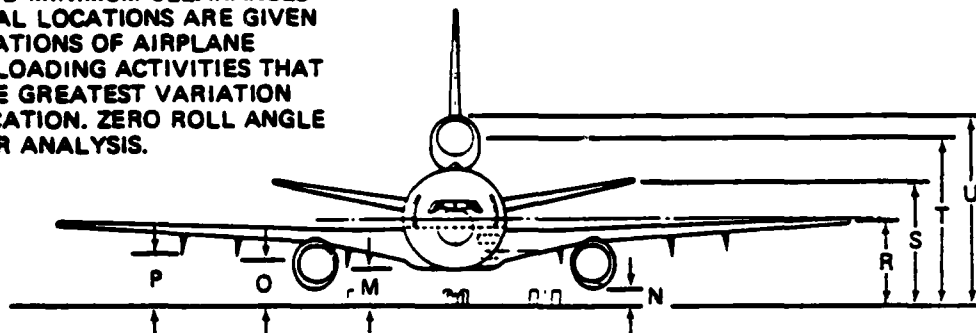


Figure 2-42 (1) DC10 Cargo Door Area Clearances



MAXIMUM AND MINIMUM CLEARANCES OF INDIVIDUAL LOCATIONS ARE GIVEN FOR COMBINATIONS OF AIRPLANE LOADING/UNLOADING ACTIVITIES THAT PRODUCE THE GREATEST VARIATION AT EACH LOCATION. ZERO ROLL ANGLE ASSUMED FOR ANALYSIS.



VERTICAL CLEARANCE						
	NOMINAL CLEARANCE MAX RAMP WT NOMINAL CG		MIN CLEARANCE CRITICAL WT AND CG		MAX CLEARANCE CRITICAL WT AND CG	
	FT-IN.	METERS	FT-IN.	METERS	FT-IN.	METERS
A	27-2	8.28	27-1	8.25	28-1	8.56
B	17-5	5.31	17-3	5.26	18-7	5.66
C	15-10	4.83	15-9	4.80	16-11	5.16
D	7-5	2.26	7-4	2.24	8-4	2.54
E	15-9	4.80	15-8	4.78	16-7	5.05
F	9-2	2.79	9-1	2.77	9-11	3.02
G	15-7	4.75	15-6	4.72	16-1	4.90
H	8-10	2.69	8-9	2.67	9-7	2.92
**I	9-3	2.82	9-1	2.77	10-0	3.05
J	15-4	4.67	15-1	4.60	16-1	4.90
K	29-11	9.12	29-6	8.99	30-11	9.42
L	57-7	17.55	57-2	17.42	58-7	17.86
M	7-9	2.36	7-9	2.36	8-5	2.57
N	2-11	0.89	2-10	0.86	3-7	1.09
O	9-8	2.95	9-7	2.92	10-6	3.20
P	10-9	3.28	10-8	3.25	11-10	3.61
R	14-8	4.42	14-4	4.37	16-3	4.95
S	23-10	7.26	23-5	7.14	24-10	7.57
T	32-5	9.88	32-3	9.83	33-3	10.13
U	36-10	11.23	36-7	11.15	37-8	11.48
*V	15-9	4.80	15-6	4.72	16-4	4.98
***W	10-3	3.12	10-0	3.05	11-1	3.38

*CF VERSIONS ONLY

**STANDARD CENTER CARGO COMPARTMENT

***EXTENDED CENTER CARGO COMPARTMENT

Figure 2-42 (2) DC10 Cargo Door Area Clearances

- ULD/Aircraft Alignment: Proper alignment of loads transferred to aircraft roller/restraint systems is most critical with the longer ULD's (ISO Containers, pallet trains, etc.). Misalignment can cause the ULD to bind or lift out of the restraint guide rails of the aircraft. Correction of and recovery from this condition is hazardous and difficult, even with smaller size and weight ULD's.

2.3.1.3 Forklifts. One of the functions of forklift trucks is loading/unloading K-loaders. To perform this function, clearance must be provided for the forklift tines. Deck tine troughs are provided on current K-loader.

2.3.1.4 Roller/Conveyor MHE. Many of the MHE in the system have roller conveyor decks. These include the K-loaders, elevator loader, lower lobe loaders, and trailers. Interface with these other MHE is required or should be anticipated. No severe constraints seem apparent for the interface requirement between the ATL and other MHE.

2.3.1.5 Container Handling Equipment. It was noted in Section 2.1.4.5, that current (or planned) CHE is either top-loading or forklift. Provision for interfacing forklift CHE and ATL is the same as forklift, i.e., tine troughs. For top-loading CHE, overhead and side clearance must be considered for the load transfer function between CHE and ATL.

2.3.2 Air Transportability

The mission of the ATL requires that it must be air transportable.

Military aircraft have both cargo compartment dimensional limitations and cargo compartment floor and ramp load limits. In addition to the compartment dimensional limits (width and height) there are loading ramp clearance limits.

The impact of these aircraft limits is the severest constraint for the ATL's configuration and weight. Either singly or in combination, these limits constraint the ATL as regards,

- Overall Dimensions
- Ground Clearance
- Approach/Departure Angle (overhang)
- Wheelbase
- Axle Spacing
- Axle Articulation
- Axle Load
- Tire Load
- Unladen (curb) Weight

The severity of the aircraft limits is best illustrated in the C-141B loading procedure for the 40K Loader (Ref: T.O. 1C 141B-9). Because of excessive axle loads, 130 feet of 2" x 12" wood shoring is required (See Figure 2-43) and crest limits at the ramp require approach build-up shoring (See Figure 4-44). The loader is winched onto the aircraft, rear first. The transport width of 120 inches allows only 1-5/8 inches clearance on each side of the aft cargo opening. Although achievable, air transport of the 40K loader on the C14B is accomplished with an apparent increase in cost, loss of time and risk of mission failure (for lack of ramp build-up shoring).

These same special procedures and waivers can be made available for and can be considered in establishing performance/requirements parameters for the ATL. But in the interest of the "readiness" factor in the mission equation and also recognizing the cost and inefficiency of these special provisions,

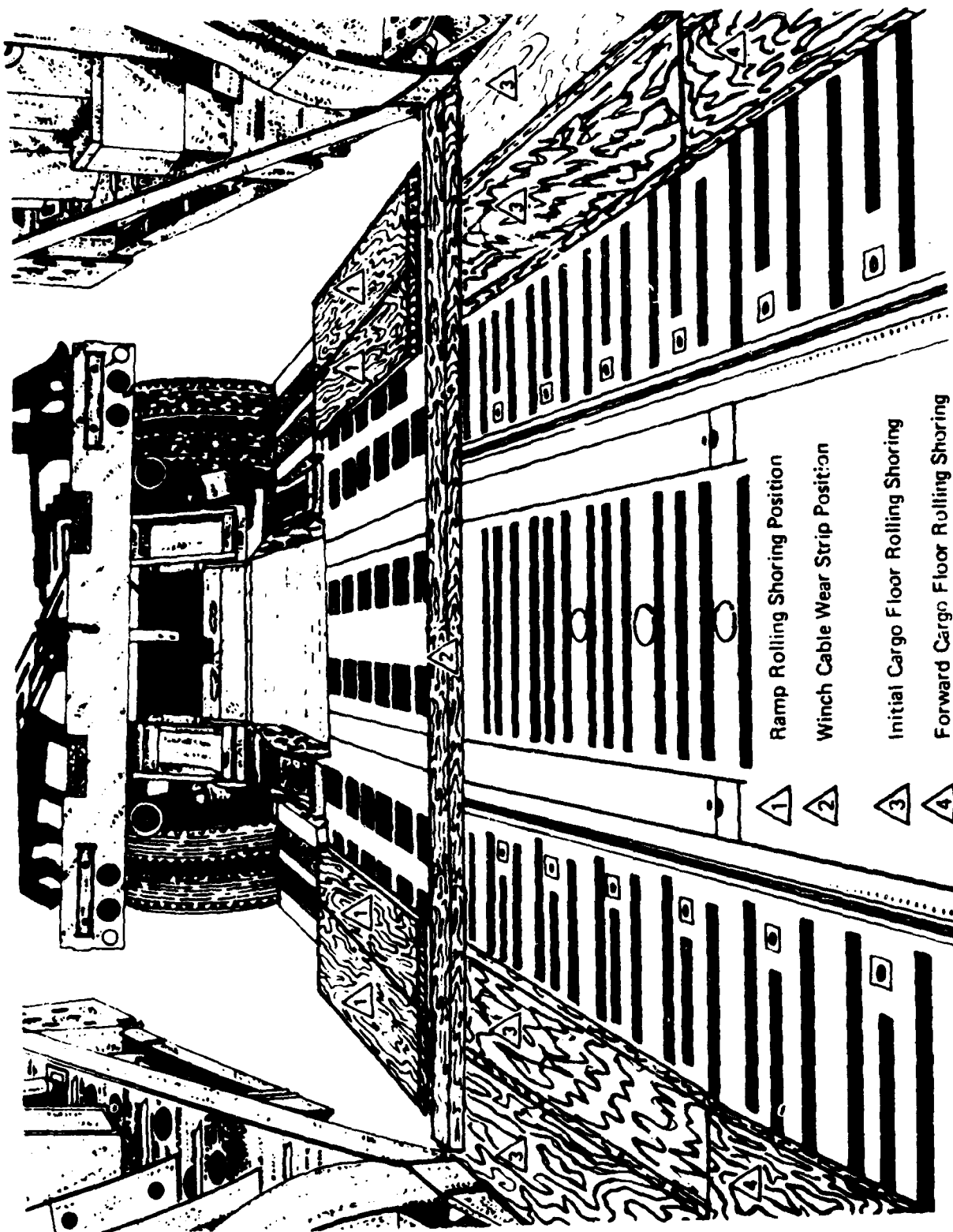
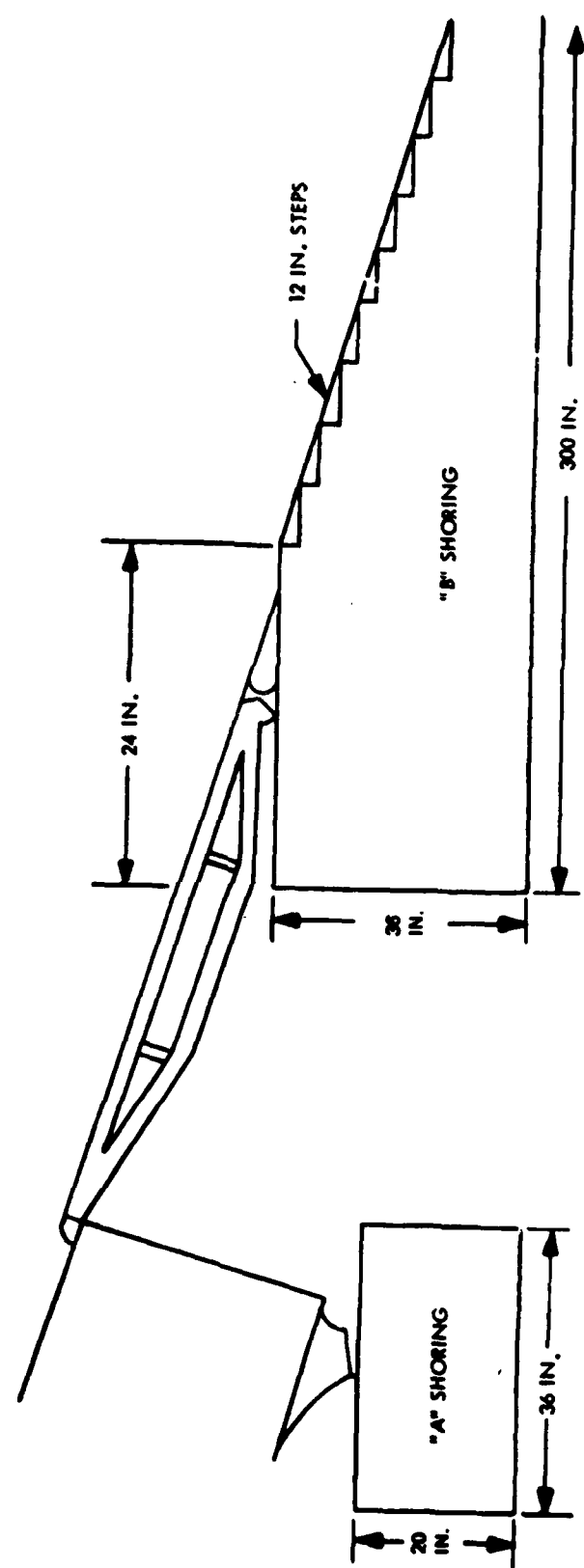


Figure 2-43 Parking and Rolling Shoring for 40K Loader of C-141B

NOTE

SHORING SIZE MAY BE INCREASED/DECREASED TO PROVIDE SUFFICIENT CLEARANCE BETWEEN RAMP HINGE, AUXILIARY GROUND LOADING RAMPS AND LOADER'S UNDERCARRIAGE.



"A" SHORING: 36 IN. LONG X 12 IN. WIDE X 20 IN. HIGH (APPROXIMATELY).
 "B" SHORING: 300 IN. LONG X 36 IN. WIDE X 36 IN. HIGH (APPROXIMATELY).

Figure 2-44 Ramp Approach Buildup Shoring

the ATL must be air transportable in the C-141B, C-5 and C-17 with the following conditions:

1. Axle and tire loads must be in compliance with cargo compartment and ramp load limits. (No parking or rolling shoring).
2. Size and configuration must be within the clearance criteria of the cargo compartment and ramp opening. (No ramp build-up shoring or clearance limit waivers).
3. Axle articulation, axle spacing and wheel base shall be adequate to permit negotiation of the loading ramp while maintaining axle/tire loads within the prescribed limits.
4. Maximum preparation time (2 hrs) is required for air transport.

2.3.3 Integrated Logistics Support (ILS)

The ILS concept provides for early analysis of equipment design to effect maximum maintenance support, minimized personnel skill levels and timely (when-required) repair parts; all accomplished with minimum life cycle cost. The ILS objective is to produce a system incorporating the necessary logistics support capability in an efficient and effective manner.

The current MHE logistics support system for K-loaders exhibits limitations which manifest themselves in low or marginal availability (in-commission rates). These limitations are evident in low reliability (MTBF = 15 Hrs) and long lead times for spares (see Appendix B) and low human reliability (see Appendix C), which result in loader disabling incidents. These logistics limitations strongly suggest that an ILS program be incorporated as an integral part of the acquisition process for an ATL; one that begins at program initiation and continues through the life of the system. A detailed discussion of and recommendation for an ILS plan are contained in Appendix A.

An ILS package provides guidance for implementing ILS considerations during design, development, production, testing, and fielding of a new system. The constraints of an ILS package depends on the methodology used in developing support management techniques, program controls, and task procedures to be implemented on a future aircraft loader. The following areas concern the constraints of support element functions required within an ILS package.

2.3.3.1 Logistics Support Analysis (LSA). The constraints of LSA revolve around the availability of the Logistics Engineer to participate in early design considerations so as to influence the incorporation of ILS criteria including supportability, maintainability and reliability. This LSA process is an iterative analytical process that aids in the determination and documentation of logistic support criteria or constraints on system design; consideration of these criteria/constraints; and validation that the final system is still feasible in terms of total logistics support. In addition to influencing design, the Logistics Engineer by using the LSA process, is required to develop and define the most effective, efficient and economical support for a given system end item. This process then ensures that techniques such as commonality of LRUs, and SRUs, low level of maintenance, and high reliability design helps to guarantee the maximum effectiveness and efficiency of system and subsystem maintenance. Thus, the LSA process identifies the characteristics and constrains that the support system may impose on the loader system availability. LSA then allows the logistics engineer to identify any potential support problems and perform tradeoffs as required. The LSA is designed to maintain the support system's compatibility, consistency of test and repair and filter this information to other ILS functions (i.e., T.O.s, Provisioning, Spares, Training, etc.).

2.3.3.2 Training. The constraints of training personnel to perform maintenance on a future aircraft loader is based on the following:

1. Complexity of newly acquired system
2. Identification of maintenance personnel skill levels
3. Type of training plan
4. Training facilities
5. Training materials/devices/aids/equipment
6. USAF and/or contractor instructors and training personnel

This training scenario should optimize the use of LSA during the development of the training plan with access to prototype configurations being considered.

2.3.3.3 Technical Manuals (T.M.). The technical manuals, used by maintenance personnel must not exceed their level of expertise. Used in conjunction with training, the T.M. identifies the most maintainable and supportable means to perform loader maintenance. Areas affected by system constraints for the T.M.s are as follows:

1. Top down break-down vs. functional group codes
2. Educational level of T.M.s
3. Incorporation of commercial hardware data
4. Incorporation of common hardware data
5. Skill level of maintenance personnel
6. Manuals should be stand-alone and reflect the latest design configuration
7. Validation and verification procedures
8. Standardization procedures
9. Availability of vendor/subcontractor information
10. Technical Manual Development and distribution methods

2.3.3.4 Provisioning/Repair Parts. Provisioning is constrained by source data acquired through the LSA process. Provisioning documentation should be prepared in top-down generation breakdown sequenced by the Logistics Support Analysis Control Number (LSACN) to the lowest replaceable piece part. Thus the provisioning documentation should include the following data:

1. Manufacturers part number
2. Reference Number Category Code (RNCC)
3. Reference Number Format Code (RNFC)
4. Federal Supply Code for Manufacturers
5. Quantity End Item
6. Additional Reference Number
7. Drawing Number
8. Shelf Life (SL)
9. Production Lead Time (PLT)
10. Unit of Measure Code (UM)
11. Overhaul Quantity, if required
12. Source, Maintenance, Recoverability Codes (SMR)
13. Failure Factor I, II, III, if required
14. Copy of drawing, if required
15. Item name
16. Type of item code
17. Essentially Code (EC)
18. Unit Prices

The supply support element is a vital function to the integration of ILS since the lack of a repair part may require that an expensive component be removed and shipped to another facility. Accomplishing this element depends upon both the Integrating Contractor and the Military Airlift Command.

2.3.3.5 Transportability/Packaging. Transportability and packaging of a future aircraft loader is an inherent design consideration and considered a constraint to design engineering. This area is significantly important in acquiring a new loader due to transportation requirements of the Military Airlift Command.

2.3.3.6 Facilities. The use of existing maintenance facilities for maintenance and repair of a future aircraft loader should be considered through the LSA process. The constraints of the facilities exist until the following requirements can be responded to in a manner that may facilitate repair time and functions:

1. Space, volume, capital equipment, utilities needed for maintenance
2. Environmental systems required for maintenance
3. Storage/shelf-space for repaired/repair parts
4. Storage environments
5. Designated facility and storage areas agree with LSA and human factors data.

2.3.3.7 Tools and Support Equipment. Design constraints to using existing tools and support equipment eliminates the need to introduce specialized equipment for loader maintenance. This area should also be addressed as a significant item during the early stages of design. The considerations for using existing equipment in the government inventory vs. peculiar equipment procurement are stated but not limited to the following:

1. Item cost of peculiar equipment
 - engineering design
 - tooling
 - lead times

2. Training
3. Provisioning
 - repair parts
4. Maintenance of Peculiar Support Equipment (PSE)

2.3.3.8 Parts Inventory. The integrating contractor for the future aircraft loader, through contractual agreement, should maintain an inventory of spares consisting of: major assemblies, components etc., to repair the loader. This inventory should be capable of transitioning from peacetime inventory to wartime without losing the acceptable level of availability needed to support the Military Airlift Command. The following areas are based on provisioning to determine inventory levels.

1. Operating level
2. Safety shock
3. Reorder cycle
4. Procurement lead time
5. Pipeline
6. Order pilot

A surge level analysis using the Failure Mode Effects and Criticality Analysis, MTBF, MTTF etc., is needed for a finite wartime surge inventory for the above 6 items.

2.3.3.9 Field Service. Field Service Engineers provide training for on-site customer personnel as required in system operation and maintenance. The field service engineer can demonstrate correct malfunction isolation procedures for a major assembly, subassembly or component. Using system knowledge, field engineers can recognize and emphasize the need for fast and accurate repair

action. This can be accomplished by training maintenance personnel in methods and procedures necessary to restore the loader to an availability status as quickly as possible, with a minimum of spare parts. Areas for Field Engineer support during the system life cycle are:

1. Installation/Integration
2. System handoff
3. Maintenance assistance
4. On the job/follow-on training
5. Field service support

2.3.3.10 Configuration Management. Engineering changes made to the loader must be controlled by a Configuration/Data Management (CDM) group. CDM responsibilities are for the preparation of any specifications and the establishment of functional, allocated and product baseline. The ILS Manager/Logistics Engineer should be a part of a Configuration Control Review Board, participating in the review of specifications, drawings, system equipment changes, and engineering change proposals/orders. All proposed changes should be evaluated from an ILS viewpoint with logistics impact identified, documented and evaluated via the ILS process.

2.3.4 Reliability, Availability, Maintainability and System Safety

Operational availability (i.e, the percentage of calendar time that a loader is available to perform its mission) is a function of both reliability and maintainability. The relationship between these factors is complex and involves other factors, as well. This relationship is discussed in more detail in Appendix B.

The relevance of the relationship is that reliability factors (MTBF) and maintainability indices (MTTR, MR, etc.) directly determine the availability. Successful mission completion for an ATL is time-sensitive, i.e., successful completion is determined by its availability to perform the mission. It follows that a prescribed level of availability is achieved and assured with designed-in reliability and maintainability. Appendix A contained the outline for a comprehensive ILS plan, which includes provisions for time-phased inputs for reliability and maintainability. The salient point is the same as for ILS; early input, during the design phase, for reliability and maintainability. The desirability and need for this approach is apparent in the estimated MTBF for current 40K loaders: 15 hours (see Appendix B). Although estimated with limited input data 15 hours is still an order of magnitude lower than can be achieved with a comprehensive program. Appendix B provides a detailed treatment of the following:

- Existing loader reliability, maintainability and safety problems.
- Design requirements/techniques/criteria for reliability, maintainability and system safety.
- Recommendations for program plans for reliability, maintainability and system safety.

2.3.5 Human Factors Engineering

A sample task analysis of the cargo transfer operation from a 40K loader to an aircraft was conducted as part of the study. Results of this analysis indicate an estimated task error probability score of 0.24 and a human reliability of 0.76 (refer to Appendix C). This T.E.P. score of 0.24 is low for the critical operator/machine interface.

Certainly, this estimated low score indicates that development of a future ATL include specific, well-defined human factors engineering criteria. These criteria identify and quantify the constraints, which result from the employment of personnel within the "system" based on safety engineering, the limits of human performance and the availability of certain skills within the user manpower pool.

Identification of these constraints and their potential impact on the ATL design require early input of human factors engineering criteria. A systematic program plan providing for criteria identification and input is essential in the overall development/design effort and can be accomplished similarly to or as part of the ILS program plan illustrated in Appendix A.

The sample task analysis is outlined in detail in Appendix C: Human Factors Engineering Study and Evaluation of Current and Future Aircraft Loaders. The HFE Study and Evaluation (Appendix C) includes:

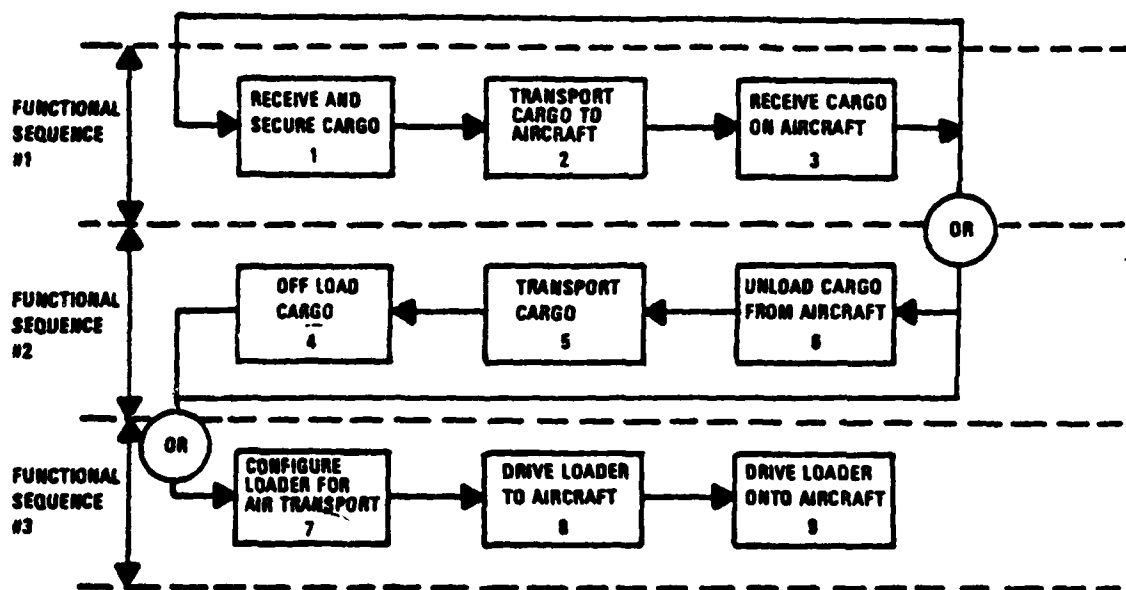
- Methodology used in the sample task analysis
- HFE basis of measurement for the analysis
- Results of the sample task analysis
- Recommendations for:
 - Key geometric and dimensional features for the operator's cab
 - Operator seat/restraint
 - Controls displays
 - Operator training

These recommendations provide for the operating environment and associated arctic and NBC clothing and gear.

Section 3

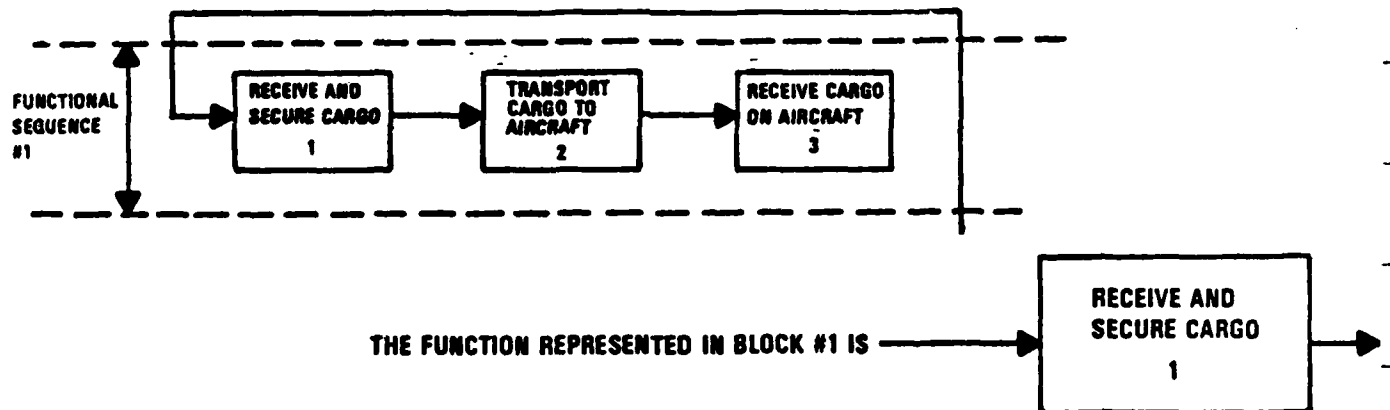
FUNCTIONAL IDENTIFICATION

The purpose of this report is to develop the optimum performance parameters for a future Aircraft Transporter Loader (ATL). These parameters are, in fact, functional requirements and section 2.0 of this report has been devoted to a detailed analysis of those factors, which influence the selection of these parameters. A simple functional flow diagram as shown below illustrates the identification of functions for the ATL.



From the Functional Flow Block Diagram (FFBD) shown above, it becomes readily apparent that there are two major functional sequences in the deployment of the ATL. Functional sequence No. 1 is to "receive, transport and load cargo on aircraft". Functional sequence No. 2 is to "unload cargo from aircraft, transport and off-load cargo". Functional sequence No. 3 depicts the requirements when the ATL is to be air transported.

With the functional flow diagram completed it becomes possible to start looking at the individual functions. Selecting functional sequence No. 1 as a place to start, we can now look at each functional element in greater detail.



Two obvious questions come to mind.

1. How is the cargo received?
2. What kind of cargo?

Referring back to sections 2.1.3, 2.1.4 and 2.1.6 we find the following:

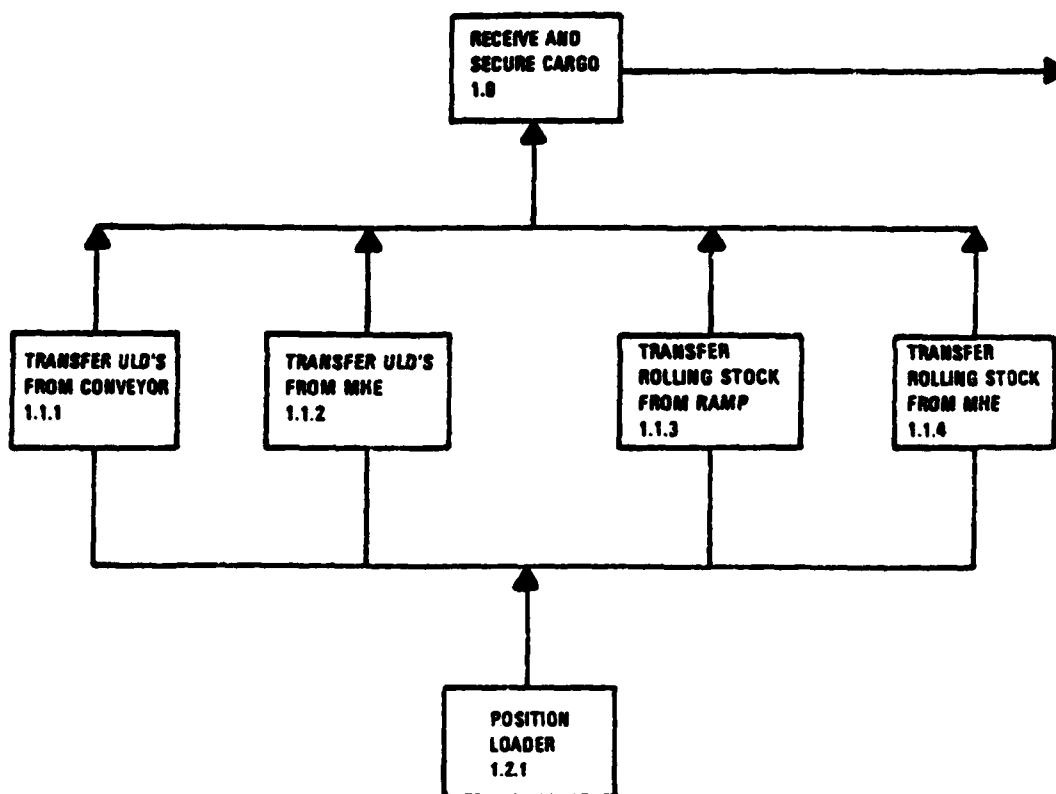
CARGO RECEIVED

1. 463L pallets (HCU-6E)
2. Platforms (type II, AE-29-1 metric, type V)
3. Container/Tactical shelters
4. LD containers
5. Rolling Stock

CARGO RECEIVED FROM

1. Loading dock roller conveyor system (manual or powered)
2. Roller conveyor truck bed (manual or powered)
3. Fork Lift
4. Crane
5. Container handler
6. Ramps

Expanding the functional block diagram to include the sub-functions:

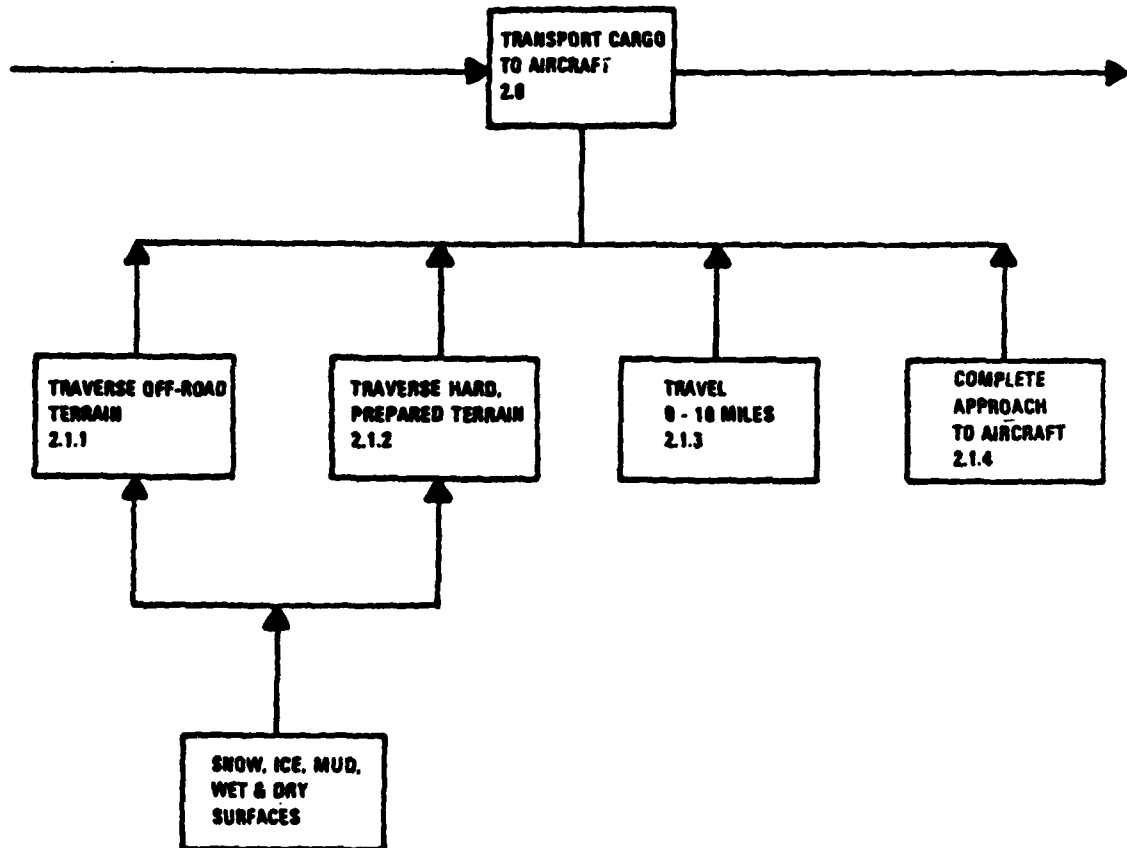


The block diagram illustrates those sub-functions which culminate in the cargo being received by and secured on the loader. While self explanatory, the diagram shows the sequence of functions starting with the loader being positioned to align with:

1. Roller conveyor systems
2. MHE (Fork lifts, cranes, container handlers)
3. Rolling stock (from loading dock, ramps, etc.)

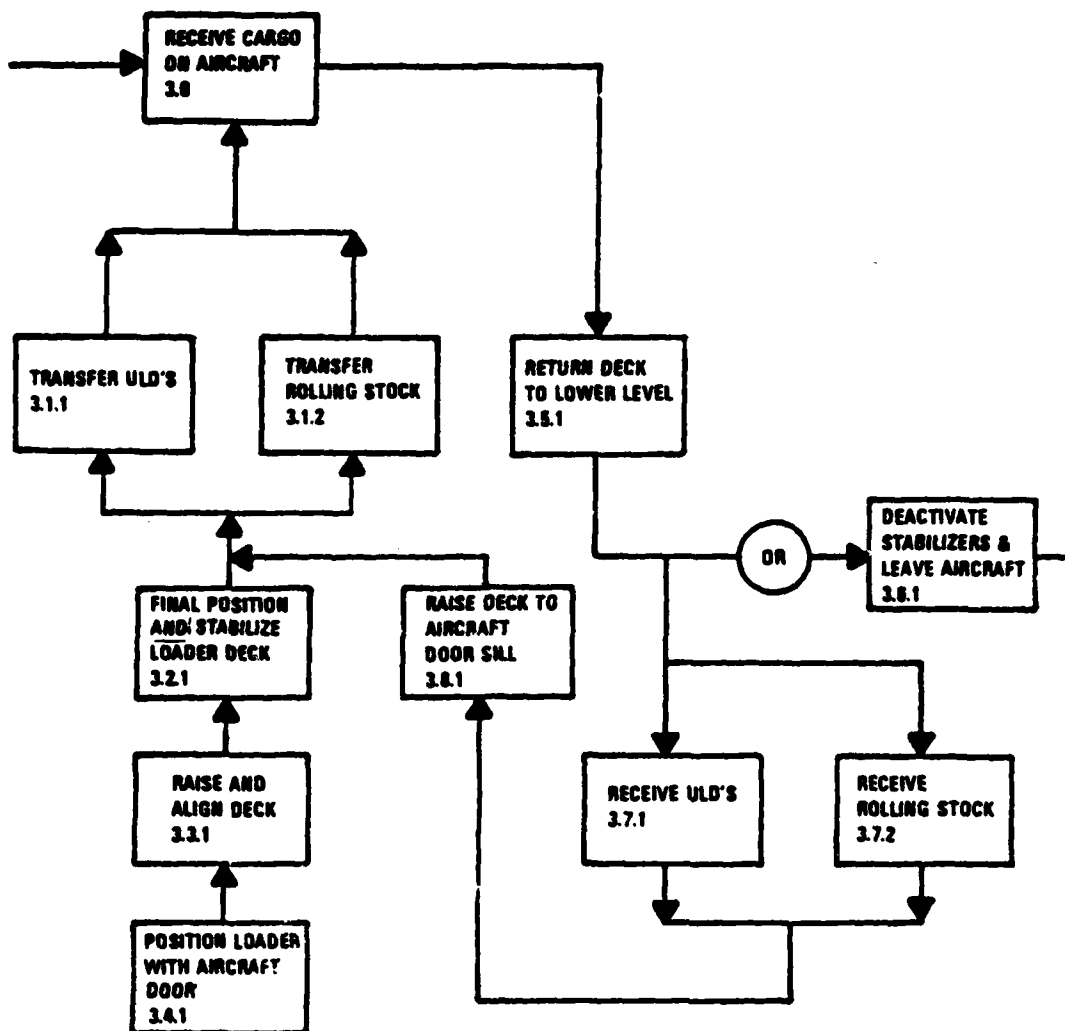
After alignment, cargo is transferred to the loader where it is secured.

Moving to block No. 2 and again going through the exercise of sub-function identification, we arrive at the following:



The function of the loader as illustrated by this sub-system is to transport cargo to the aircraft. Reviewing the diagram, it becomes evident that the cargo must be transported over rough terrain (off road) and on prepared surfaces (airport landing strip and apron conditions). Cargo must be transported over a variety of tractive surfaces including: snow, ice, mud, etc. Distances traversed are typically up to two miles and can be up to ten miles and the turn radius capability of the loader is critical when approaching certain aircraft.

Moving to functional block No. 3 and again delineating the sub-functions:



Analyzing the sub-functions, it is important to draw attention to some basic differences between the "receive and secure cargo" cycle (Block No. 1) and the "receive cargo on aircraft" cycle (block No. 3). when cargo is transferred from the loader to the aircraft, transfer can only be made by one of two methods:

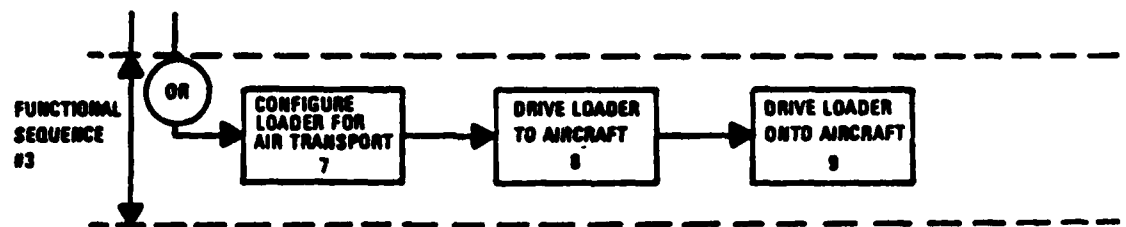
1. Rolling stock (roll-on/roll-off).
2. ULD'S transferred by roller conveyor system.

The aircraft is equipped with the 463L roller system, as is the loader.

This is the only transfer system (with the exception of roll-on/roll-off stock) and it is this system which is the common denominator for all military air cargo transfer.

Functional sequence No. 2 is, for all practical purposes, the reverse of functional sequence No. 1 and the sub-systems should be similar. Therefore, no useful purpose is served in re-analyzing these functions here.

One of the essential elements of the military mission is that the ATL be air transportable. Functional sequence No. 3 represents those functions which constitute the requirements for air transport of the ATL.



Section 4

PERFORMANCE REQUIREMENTS ANALYSIS

Section 2.0 (System Requirements) of this report has been devoted to an extensive review of military and commercial aircraft cargo handling systems with the objective of developing the optimum performance requirements for a future Aircraft Transporter Loader (ATL). Considered in this review were: The 463L cargo handling system, military and commercial pallets and containers, military platforms, 463L MHE, commercial and military aircraft, some one-hundred and sixteen different cargo loaders - both foreign and domestic, terminal and environmental interfaces, and other factors and constraints, which have a decided influence on the requirements for a future ATL.

In Section 3.0 a functional flow block diagram was developed and expanded to identify the individual functions, which are associated with the development of a future ATL. Although simplistic in nature, the functional flow block diagram proves to be a valuable tool which graphically demonstrates the activities or functions which the ATL is expected to perform. With the functional requirements identified, it is now possible to utilize the information generated and reviewed in Section 2.0 to zero in on the performance requirements for the ATL.

The purpose of this section is to establish the recommended performance requirements and parameters which can be used for the development of a final set of hardware specifications for the ATL by the USAF. Some of these performance requirements are going to necessitate a series of trade-off's in order to come up with the viable recommendation, others are going to be so obvious, no trade-off will be necessary.

4.1 BASIC CONCEPT OF THE ATL

As this report has progressed, certain performance characteristics have become quite apparent. The mission definition and functional identification detailed in previous sections are those of the 40K and 25K loaders. Its understandable that some of the performance requirements which will follow are so obvious, they almost need no explanation. With the existing 40K loader, its just about impossible not to conceptualize the ATL. Therefore, its appropriate to speculate that the ATL will, at least, be a transporter-loader similar in concept to the 40K loader. One which extends the existing performance capabilities of the K-loaders and also provides new and additional capabilities, which cover the current performance shortfall and anticipates new future performance requirements. This observation is not intended to exclude other possible ATL concepts, but is stated in recognizing that the initiated reader/reviewer will automatically preconceive a K-loader in the following performance requirements analysis. In fact, rather than risk defining the performance requirements too abstractly, it is convenient to make reference to K-loader performance characteristics for a clear and concise understanding.

Several of the basic concepts of an ATL result from the physical characteristics of the total 463L system and bear mentioning.

1. 463L Capability

The 463L system is a roller conveyor system. All the ULD's are designed or adapted to be handled by a roller conveyor system. The aircraft, terminal and cargo ground handling systems are all fitted with roller conveyor systems. This basic ULD concept represents an enormously successful approach to air cargo handling and is completely integrated into the USAF air cargo system. A roller conveyor system has to be a leading candidate for the ATL cargo deck.

2. Transporter-Loader Concept

In the transport mode, the ATL is a cargo truck. In its' complete function, it's a cargo truck with an elevatable cargo bed. As such, it easily falls into the category of other system MHE - self-propelled, diesel-powered, hydraulically actuated. Maintenance and operating personnel, procedures and facilities are in place to support this type of equipment. Therefore, it is likely that the ATL should be a diesel-powered, hydraulically actuated unit.

3. Air Transportability

The self-propelled truck concept is essential to the definition of air transportability established in Section 2.3.2, i.e., that is, the ATL must load itself, unassisted, into the transport aircraft. In Section 2.3.2, the load limits were referred to as axle and tire loads. Again, the assumed concept of a self-propelled truck can be further augmented to be an axle supported and driven vehicle using pneumatic tires. The load criteria limits for solid rubber tire or tracked vehicles are more severe than for pneumatic tires and almost certainly require parking and rolling shoring.

In summary, the basic concept for the ATL is a self-propelled, diesel-powered, hydraulically actuated vehicle with an elevatable roller conveyor cargo bed, with tractive effort provided by axle driven pneumatic rubber tires.

4.2 STRATEGIC VS. TACTICAL ATL

Section 2.1.1.1 reviewed the two distinct airlift capabilities of MAC: Strategic and Tactical. The Congressionally Mandated Mobility Study (CMMS) published in 1981 recommended adding 20 million ton-miles per day of

inter-theatre airlift to a 1986 projected capability of over 46 million ton-miles per day. To cover the 20 MTM/D shortfall in airlift capability, the USAF Master Airlift Plan proposes a force structure as contained in Figure 4-1. The resulting inter-theatre and intra-theatre airlift capabilities are contained in Figure 4-2. Based on the projected force structure and airlift capabilities, strategic and tactical airlift are characterized as follows:

Strategic (Inter-theatre) Airlift

- o Intercontinental Distances
- o Infrastructure - Prearranged routes, staged crews
- o Aircraft: C-141B, C-5, C-17, KC10 CRAF
- o Operating Environment: Developed, paved hard-pan terrain
- o Cargo Capability: 66 MTM/D

Tactical (Intra-theatre) Airlift

- o Short Distances
- o Flexibility - Tactical Mobility
- o Aircraft: C-130, C-17
- o Operating Environment: SAAF; Semi-prepared, and rough terrain

In comparing these airlift characteristics, the salient features which impact the performance characteristics of a loader are the aircraft serviced, the operating terrain and the aircraft available for air transport. This duality in airlift mission confirms the current USAF strategy for K-loaders, i.e., the 25K and 40K loaders for strategic operations, the TAC loader for tactical operations. The projected force structure does not alter this strategy because the C-130 will continue to perform tactical airlift operations

PROPOSED FORCE STRUCTURE

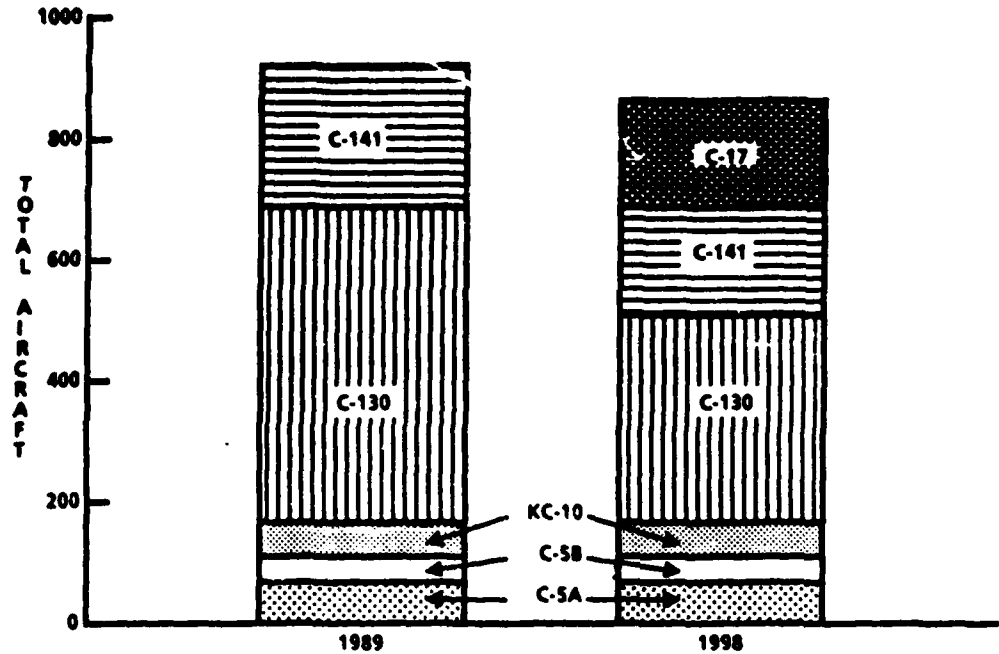


Figure 4-1 Proposed Force Structure

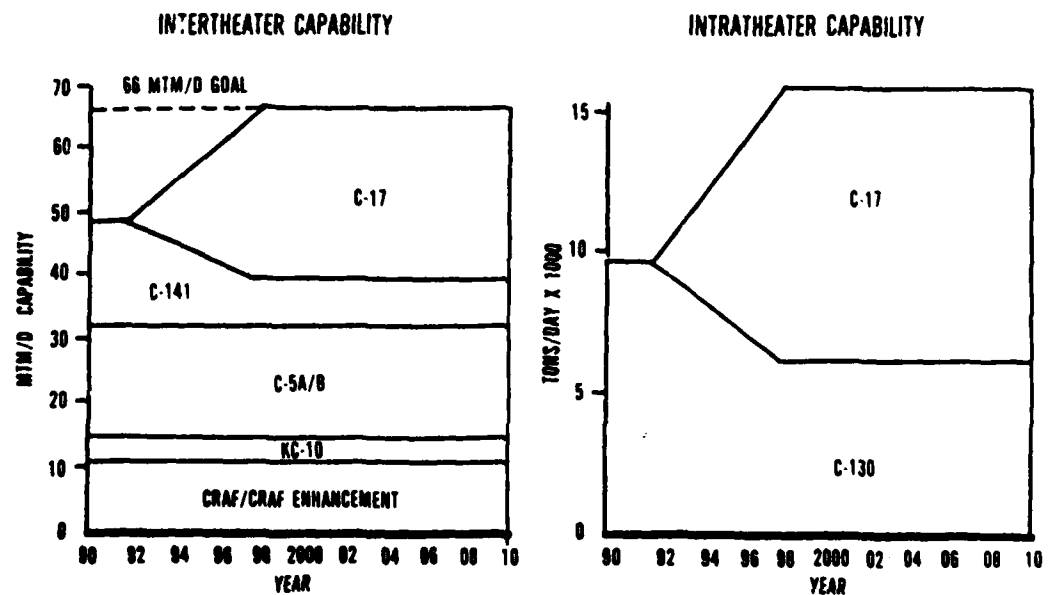


Figure 4-2 Intertheater Capability

beyond the turn of the century. The rationale to support the continued validity of two types of loaders is as follows:

- The strategic loader will include capabilities to service all MAC and CRAF aircraft in the system. As such, it will provide capabilities not required for tactical operations, i.e., lift height capability beyond that of the C-130 and C-17 is not required.
- The tactical loader will provide mobility and maneuverability for SAAF locations not required for strategic ports.
- Weight and size of the strategic loader will exceed the payload capability of the C-130, as evidenced with the 40K loader.
- Weight and size of the tactical loader is limited by the payload and load criteria of the C-130.

The two types of loaders required for the projected airlift capabilities have the following characteristics:

Strategic Loader

- Maximized Capacity (payload and deck length) for all ULD's
- Limited off-highway capability
- Service all aircraft (MAC & CRAF)
- C-141B, C-5 and C-17 Air Transportable
- Weight & Size within C-141B allowables
- Large Population - Based on inter-theatre cargo volume

Tactical Loader

- Lower Capacity - Based on tactically-deployed ULD's
- Rough-terrain capability
- Service C-130, C-17 & ATT
- C-130 (C-141B, C-5, C-17, & ATT) Air Transportable
- Small Population - Based on intra-theatre ULD cargo volume

The current TAC loader performs this tactical mission. It has the capacity required (25,000 pounds) to handle 463L pallets and 20 foot containers and shelters and (36,000 pounds) to handle airdrop platforms. It's ability to negotiate rough-terrain peculiar to a SAAF is well proven with the all-wheel (8X8) drive system. It is C-130 air transportable.

The shortfall in loader capability is in strategic operations, primarily in lift capacity and height. The "loader of the future" described and identified by the USAF is a strategic loader (aircraft transporter-loader).

4.3 AIR TRANSPORTABILITY

In Section 2.3.2, it was observed that aircraft cargo compartment floor load limits and dimensional clearance limitations place constraints on the configuration and weight of an air transported vehicle. The C-141B constraints are more limiting than those of the C-5 or those planned for the C-17.

Before continuing with a detailed performance requirements analysis, the impact of these constraints will be reviewed to establish the effect they have on the ATL's configuration and weight.

1. UnLaden (Curb) Weight

The cargo weight and load distribution capability of the C-141B are collectively contained in:

- o Figure 4-3, Maximum Axle and Wheel Weights for Vehicles with Pneumatic Tires
- o Figure 4-4, Cargo C.G. Limits

MAXIMUM AXLE AND WHEEL WEIGHTS FOR VEHICLES WITH PNEUMATIC TIRES												
COMPARTMENT	TREADWAYS				BETWEEN TREADWAYS				OUTBOARD OF TREADWAYS			
	LOADING/ OFF-LOADING		FLIGHT		LOADING/ OFF-LOADING		FLIGHT		LOADING/ OFF-LOADING		FLIGHT	
	MAX AXLE	MAX WHEEL	MAX AXLE	MAX WHEEL	MAX AXLE	MAX WHEEL	MAX AXLE	MAX WHEEL	MAX AXLE	MAX WHEEL	MAX AXLE	MAX WHEEL
	14	15	16	17	18	19	20	21	22	23	24	25
	AXLE	WHEEL	AXLE	WHEEL	AXLE	WHEEL	AXLE	WHEEL	AXLE	WHEEL	AXLE	WHEEL
C	32500	7500	10000	5000	12000	3000	5000	1250	32500	7500	10000	5000
D			10000	5000			5000	1250			10000	5000
E			20000	5000			4400	1100			20000	5000
F			20000	5000			4400	1100			20000	5000
G			10000	5000			3700	925			10000	5000
H			7500	5000		3000	7500	5000			7500	5000
I			7500	5000		5000	7500	5000			7500	5000
J												
K												
L												
M												
N												
O												
P												
Q												
R												
S												
T												

Figure 4-3 Maximum Axle and Wheel Weights for Vehicles with Pneumatic Tires (C-141B)

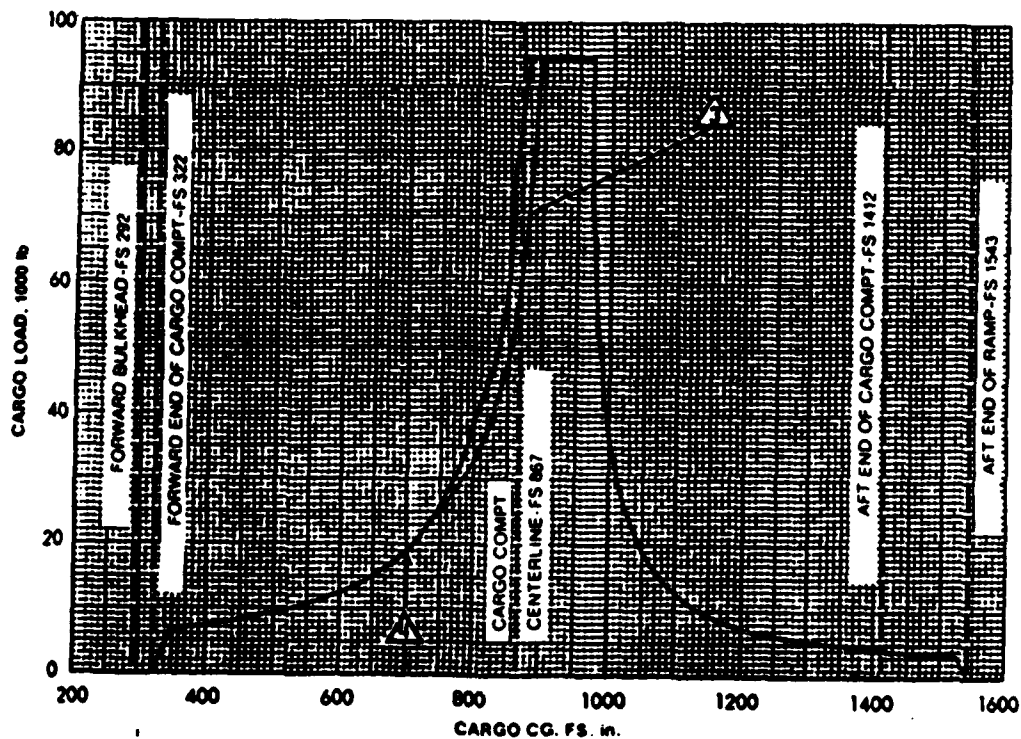


Figure 4-4 Cargo C.G. Limits (C-141B)

Figure 4-5 includes a graphic illustration of the in-flight treadway allowable axle and tire loads by compartment. As a point of reference, the axle positions of a 40K loader (354 inches) are shown. A fifth axle can be placed in compartment K or L. The fifth axle should allow a higher vehicle weight, while effecting an axle load distribution with each axle load within the allowable axle weight of each respective compartment. The C.G. restriction requires that for a vehicle weight of 60,000 pounds, (per example), the vehicle's C.G. must be located between station numbers 870 and 980 (a 110 inch span). Since the forward axles have the highest allowable load limit (20,000 pounds/axle), the weight distribution would require a 40/20 split between the forward three and rearmost two, with the rearmost axle at 10,000 pounds in compartment "O". This would be an allowable load configuration, assuming a 40/20 weight distribution can be effected. The observations made here are:

1. Axle spacing and wheelbase are limited by the aircraft's compartment lengths and weight limits.
2. When combined with the compartment lengths and axle weight limits, the C.G. restriction further restricts the wheelbase and resulting axle load distribution of the vehicle.

A six axle vehicle might be more forgiving, but it increases the vehicle weight. The effect of a sixth axle, if added to the five axle unit considered here, would be to reduce axle loads, which is not required, and permit a C.G. shift toward the center, which could be advantageous for other elements of the design, such as vehicle dynamics in acceleration and braking. For a vehicle weight of 60,000 pounds (or less), a sixth axle could allow for axle loads of 10,000 pounds or less, with an even weight distribution. The advantage would be that the total payload complement could include the ATL and another piece of MHE (e.g., a 10K Forklift). Each unit could be positioned in the aircraft

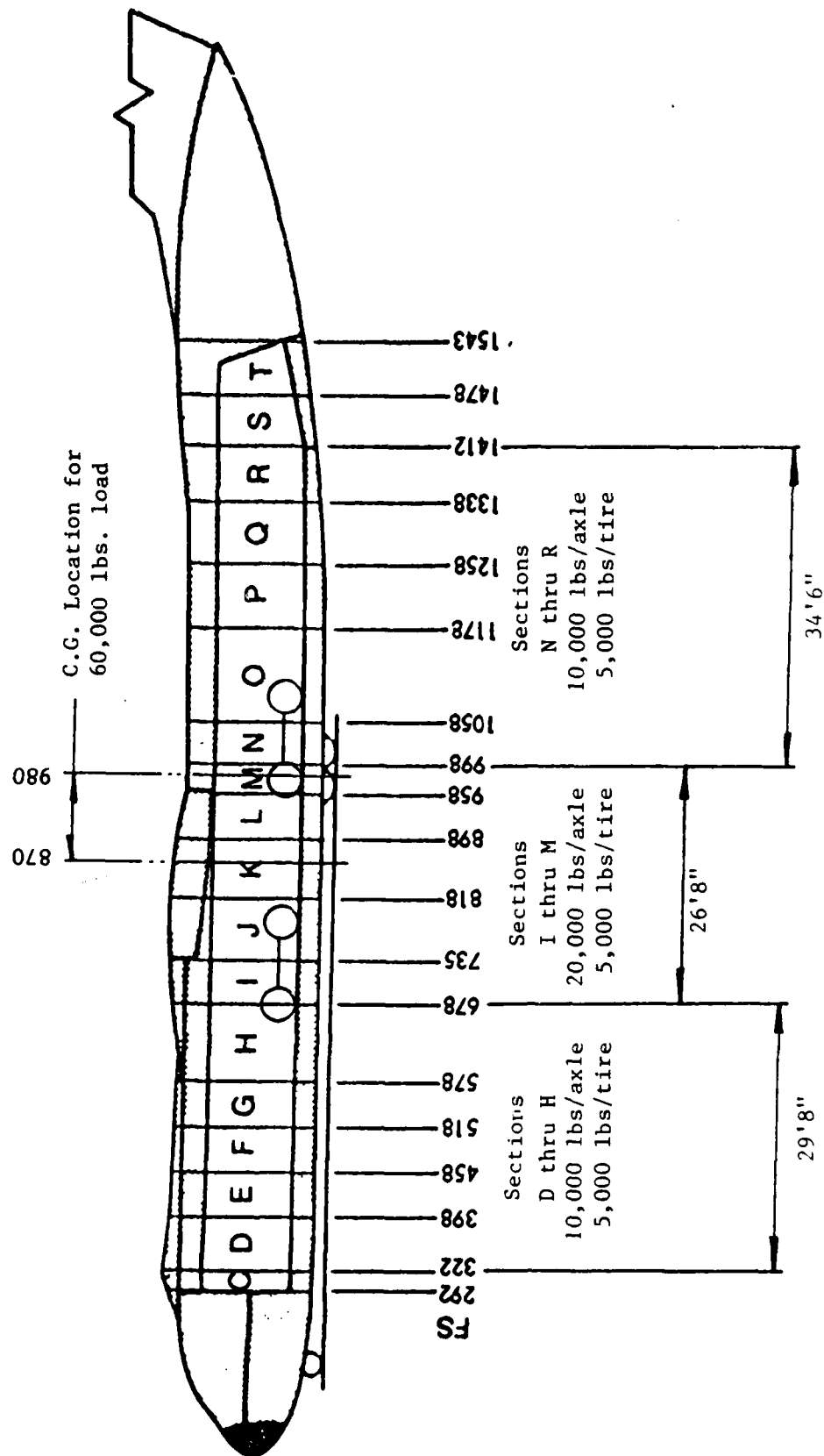


Figure 4-5 Inflight Treadway Allowable Axle and Time Loads (C-141B)

to obtain the required overall cargo C.G. location. Based on this preliminary review, the recommended maximum practical vehicle weight, based on aircraft load constraints is 60,000 pounds.

2. Configuration

The limitations on wheelbase and axle spacing noted previously have a cascading effect when looking at the C-141B ramp negotiation exercise for the ATL. The worst case negotiation geometry for the C-141B is contained in Figure 2-29. Typically, the ground clearance, approach and departure angles and overhead projection required to clear the cargo opening without interference will be dependent on the wheelbase, axle spacing and axle articulation of the vehicle. In addition to the limiting factors for wheelbase and axle spacing derived from the cargo in-flight load limits, there are requirements and limits on these vehicle parameters when considered in the design function for transport mode of the ATL. Vehicle dynamics considerations will be a function of these same parameters.

The point to be made is this: the axle suspension and articulation required to satisfy the air transportability capability stated in Section 2.3.2 as a requirement will far exceed the present capability of the 40K loader. It will probability exceed the mobility and maneuverability required for typical terrain in the transport mode. The requirement identified in Section 2.3.2 is to ensure readiness for contingencies.

4.4 PERFORMANCE CHARACTERISTICS

In this section, the major systems and/or components of the aircraft loader will be identified and the performance characteristics of each will be defined.

Those major systems which constitute a typical aircraft loader are listed as follows:

1. Deck
2. Lifting mechanism
3. Cab and controls
4. Chassis

The performance requirements for each of these systems and the rationale for selecting the requirements will be discussed in the following sections.

4.4.1 Deck

The deck is that platform which receives, secures, and transfers cargo. It elevates to meet door sill heights of aircraft and to interface with loading docks, other MHE and ramps. The cargo to be accommodated is rolling stock (wheeled loads) and 463L ULDs including palletized cargo, military platforms and containerized loads.

4.4.1.1 Capacity. In determining the load capacity of the deck, both weight and dimensional size of cargo must be considered. The capacity of the deck is primarily established by the ULDs.

Discussion:

- The longest ULD is the 40 ft. ISO air/surface intermodal container, which weights 45,000 lbs.
- The heaviest ULD is the Type V (Joint Service) military airdrop platform, projected to weigh 60,000 lbs. and be 32 ft. long.
- Two 20 ft. ISO air surface containers weigh 50,000 lbs.
- Both 40 ft. and 20 ft. ISO containers will be transported on military and civilian aircraft. Cargo deck heights range from 39" to 18 ft., 1 inch.
- The C-17 will have the maximum deck height (5 feet, 4 inches) of aircraft capable of airdropping the 60,000 lbs., 32 ft. platform.

Summary:

- If the deck accommodates (1) 40 ft. ISO container, it can also handle (2) 20 ft. containers with a combined weight of 50,000 lbs. to be raised 18 ft., 1 inch.
- A 40 ft. deck length will accommodate the Type V, 60,000 lb. platform; however, the capacity needs to be increased to 60,000 lbs. up to a height of 5 ft., 4 inches.

This would suggest a dual capacity deck, 40 ft. in. length and capable of raising 50,000 lbs. to 18 ft., 1 inch and 60,000 lbs. to 5 ft. 4 inches.

Recommendation:

Interface systems would have to be installed to lock out 60,000 lbs. above 5 ft., 4 inches, yet still permit 50,000 lbs. to be raised to 18 ft., 1 inch. Such systems would result in added cost and potential unreliability. It is recommended that the deck be designed to accommodate a cargo length of 40 ft. and be capable of elevating 60,000 lbs. to 18 ft., 6 inch.

Issue: Pallets - 5 vs. 6

The 40 ft. cargo deck will accommodate five 463L military pallets in-train (length 37.3 ft.). Since military aircraft carry pallets in multiples of six or more (C-130=6 pallets, C-141B=13 pallets, C-5=36 pallets) a case can be made for increasing the deck length to accept six pallets in lieu of five. This would result in a cargo length of 44 ft., 10 inches, an increase of 4 ft. 10 inches over the anticipated 40 ft. length.

Positive Aspects:

- Additional pallet, increased efficiency.
- Additional length for rolling stock and LD containers.

Negative Aspects:

- Increased cost.
- Additional weight and length, would compromise air transportability. Length would compound the ramp entrance problems.
- Maneuverability when approaching aircraft would be more difficult.

Discussion:

Although there are several negative factors to adding the 6th pallet, there are those who would argue that the increased efficiency is worth the price.

However, there is another aspect to be considered. Referring to Figure 2-41 (B-747 Cargo door clearance) it will be noted that the current 40K loader has approximately 8 ft. clearance between the rear-end of the loader and the flap track fairing on the wing. The 40K loader is 42 ft. long with a cargo length of 37.3 ft. Extrapolating the 44 ft. 10 inch cargo length to include the cab, etc. gives an overall length of loader equal to 49 ft. USAF Safety Standards (Ref. AFOSH 127-66 Chapter 12, Section 12.22b) requires that the operator approach the aircraft with the loader, stop a distance of 5 ft. from the cargo door, raise the deck to align with the aircraft cargo floor and then approach the aircraft with raised deck for final positioning. Referring again to Figure 2-41, it is apparent that not only can the procedure not be followed, for the increased length of the loader interferes with the wing of the aircraft, but the close proximity of the loader to the wing when the loader is at the aircraft door creates a hazardous condition. The same condition exists when servicing the DC-10 (see Figure 2-42).

Recommendation:

A loader with 6 pallet capability would create a condition which would make servicing of the B-747 and DC-10 aircraft hazardous. It is recommended that the loader deck length be sufficient to handle 40 ft. of cargo.

4.4.1.1.1 Capacity - Rolling Stock. Rolling stock is loaded into military aircraft by means of their ramp by either the ground loading or truck loading procedure outlined in Section 2.1.3.4. The ground loading procedure is

preferred, since assisting MBE is not required. Both the B-747 and DC-10 in the CRAF are used to transport rolling stock (see Section 2.1.3.4). They do not have loading ramps.

Elevator loaders are currently used to load rolling stock onto the wide-bodied aircraft. The ATL will have more than sufficient capacity for this function. Its utility as a loader will be maximized, if it is used for truck loading of rolling stock on all aircraft (or for general vehicle transport) to its' maximum capacity.

Considerations:

- To perform the rolling stock transport and loading function, vehicle gross weights and axle loads must be identified. This can be accomplished by referencing TB 55-45/AFP 76-19/NAVMC-27533, "Certification of Military Equipment for Transport in MAC/CRAF Aircraft" and TB 55-46-1, "Standard Characteristics for Transportability of Military Vehicles and Other Outsize/Overweight Equipment". These documents can be used to identify and specify rolling stock loads.
- Loads induced by rolling stock will be within the allowable axle and tire limits of the aircraft, except when parking or rolling shoring is used. The aircraft load limits can be used as guidelines in specifying ATL deck loads or load capability.
- Deck surface structure will have to accommodate both wheeled and tracked vehicle, both for traction and treadway width.
- For CRAF loading, a ground loading ramp will be required.

Recommendations:

1. ATL shall be rated to load and transport rolling stock to within its maximum load capacity and maximum deck width and length capability.
2. ATL deck shall be provided with a treadway width and surface adequate to handle specified rolling stock loads.
3. ATL will include a ground loading ramp for specified rolling stock loads. Note: Availability of assisting MBE for this ramp function (e.g. CCE Flat Bed trailer) should be assessed before imposing this requirement.

4.4.1.2 Alignment. Referring to the Functional Flow Block Diagram (FFBD) shown in Section 3.0, it becomes apparent that while the loader can receive or transport cargo from several external sources, the ultimate interface is with the aircraft. FFBD Blocks 3.4.1 through 3.1.1. define the procedural functions required to service an aircraft.

Blocks 3.4.1 Position Loader with Aircraft Door
and 3.3.1 Raise and Align Deck

USAF STD.AFOSH 127-66, Chapter 12, Section 12.2b. requires that the operator approach the aircraft with the loader and when a distance of 5 ft. from the aircraft, stop the loader and raise the deck to align with the aircraft door. This requires a fair amount of judgment on the part of the operator when servicing military or narrow-bodied aircraft with lower main decks. It is, however, quite a feat when the operator is in the cab at slightly higher than ground level and has to judge where to stop the loader in order to align with a door some 18 ft. above the ground. It may be advisable for the spotter (also required by AFOSH 127-66) to hang a plumb line or some other sighting device from the aircraft door to assist the operator in his initial alignment.

Block 3.2.1 Final Position and Stabilize Loader Deck

The operator now slowly inches the loader the remaining 5 ft. to align with the deck as closely as possible. This is important!! Because once the operator gets to the aircraft he sets his stabilizers (if necessary) and proceeds to fine tune his alignment. This approach to the aircraft and the resulting alignment is critical because once the operator stabilizes the loader, all final alignment functions must be made at the deck level. If the initial alignment is outside of the adjustment range of the deck systems, the operator must destabilize the loader, back away and re-align.

Block 3.1.1 Transfer ULDs or Rolling Stock to Aircraft
and 3.1.2

Once the deck is aligned with the aircraft, cargo can be transferred.

Discussion:

Cargo can only be transferred to or from aircraft by one method. It must be rolled! In the case of rolling stock, this is self explanatory. All other cargo is transferred to or from the aircraft by roller conveyor. The conveyor system installed on the aircraft and with which the loader must interface is the 463L system consisting of rollers, guides and locks (Section 2.1.2.1).

The conveyor system on the loader deck may well be rollers, balls, castors or some other hardware as long as it aligns and interfaces with the aircraft conveyor.

Alignment is achieved when the loader is positioned so that the conveyor and guide rails on the deck are directly in line with the aircraft conveyor and rollers, allowing palletized ULDs to be transferred with no binding or cocking. This seems like a simple enough operation when one visualizes a single pallet 108 inches wide x 88 inches long being transferred. It becomes quite another situation when a train of 5 pallets joined together (approx. 37 ft. long) or a 40 ft. long ISO container is being transferred. Just a small misalignment can cause the load to bind or jam in the rails.

In order to accomplish final alignment, the loader deck must have adjustment capability. Currently the 40K loaders have pitch, roll, side-shift and elevating capability. With the potential of handling longer loads becoming more of a reality, the addition of YAW adjustment is recommended. These alignment functions will be discussed as follows:

4.4.1.2.1 Elevate. Currently the 40K loader utilizes a hydraulically actuated grasshopper linkage to elevate the deck. Maximum elevation is 13 ft. Minimum elevation is 41 inches. The 40K loader is unable to service the higher main decks of wide-bodied aircraft.

In order to determine the elevation requirements of the ATL all aircraft, both military and commercial, likely to be serviced by the ATL were reviewed (Section 2.1.5). These aircraft were: C-130, C-141B, C-5, C-17, KC-10, DC-8, DC-9, DC-10, L-100-30, L-188, B-707, B-727-100C, B-747, C-23, C-160, G-222 and the A300-600.

Recommendations:

The recommended elevating range is 39 inches min. (C-130) and 18 ft. 6 inches max. (B-747). The minimum height of the C-130 floor is 39 inches. With the addition of the roller assemblies, this dimension increases to 41 5/8 inches. The 39 inch dimension was selected to allow transfer of rolling stock. Note: Floor height of the C-160 and C-23 is 39.4 inches. The maximum height of the main deck for the B-747 is 18 ft. 1 inch. The loader range of 18 feet 6 inches was selected to allow for addition of rollers and a pallet subfloor and deviations in terrain, etc., which will affect height. This range of elevation would appear to service all military and commercial cargo aircraft.

4.4.1.2.2 Pitch. Pitch can be described as the forward or rear tilt of the deck. The primary purpose of the pitch mode of alignment is to adjust the fore and aft level of the deck so that as cargo is being transferred to or from the aircraft, it does not have to be pushed uphill. In fact, it is not uncommon to tilt the deck slightly in the direction of load transfer in order to assist in movement of cargo.

Specifications for the 40K loader currently require that the lift linkage be capable of positioning the deck through an altitude of 6 degrees above and below horizontal.

Recommendations:

With the increased loads and the increase in elevation anticipated for the ATL, it is recommended that the acceleration of a 60,000 lb. load tilted at 6° on a conveyORIZED system be determined. Then, the design of the emergency stops can be predicated on the force required to stop such a load.

4.4.1.2.3 Roll. Roll can be described as tilting the deck from left to right or vice versa. The purpose of the roll function is to align the loader deck to be parallel with aircraft cargo decks for load transfer from the loader deck or vice versa. The limits of the deck roll angle depend upon the attitude or angle of the aircraft deck. The attitude of a standing aircraft is a function of and varies with the shifts in the center-of-gravity of the aircraft. Detailed and sequenced procedures are required and used to maintain stability of a standing aircraft during cargo loading/unloading and refueling operations. A roll angle of the aircraft about a longitudinal axis or an aircraft fuselage rotation about a lateral axis greater than 4 degrees is excessive for both cargo loading/unloading and refueling operations.

A second concern in determining the roll angle of the deck is stability of the loader during the unloading sequence, particularly for the highest deck elevation of 18 feet, 6 inches. For the highest rated load of 60,000 lbs. at maximum elevation of 18 feet, 6 inches, the change in stabilizing moment for the ATL is less than .5%.

Recommendation:

A roll angle about the longitudinal axis of the ATL deck of 4 degrees maximum is recommended.

4.4.1.2.4 Side Shift. The purpose of the deck side shift function is to permit final lateral adjustment and alignment of the loader deck guide rails with the aircraft guide rails. This final lateral adjustment is made after first maneuvering the ATL and positioning the ATL deck at the aircraft cargo door per the procedure as outlined in Section 4.4.1.2. The range of side shift adjustment is dependent on the accuracy with which an operator can execute the initial positioning of the loader deck. The 40K Loader has a side shift capability of $\pm 1\text{-}3/4$ inches. For initial alignment of the ATL deck with aircraft cargo door sills at a height of 18 feet, 1 inch, a side shift capability of $\pm 1\text{-}3/4$ inches would provide less than a minimal margin of error to the operator.

Recommendation:

A side shift capability of ± 3 inches about the longitudinal axis of the ATL is recommended.

4.4.1.2.5 YAW. The dictionary defines YAW as "to deviate from the flight path by angular displacement about the vertical axis". Perhaps an easier way to describe the YAW movement would be to visualize the deck as a rectangular platform viewed from above (plan view). If the deck were rotated clockwise about the point where the longitudinal and lateral centerlines intersect, the front of the deck would move to the right, and the rear of the deck would move to the left resulting in an angular displacement from the longitudinal centerline. It is this kind of alignment which is required in order to provide a straight line of travel from the aircraft to the loader.

Although YAW is an important adjustment, it should be noted that it is the only adjustment which the operator cannot visually sight in. All of the previously mentioned alignment functions rely on the ability of the operator to

properly sight in the mating surfaces. Since the operator cannot see behind the cab and he has no point of reference, he must depend on a spotter stationed at the aircraft cargo door to direct him.

Recommendations:

It is recommended that:

1. YAW adjustment be provided.
2. YAW mechanism be designed so that the deck can be yawed with a full rated load (60,000 lbs.) on the deck.
3. The same precautions regarding stability of the loader apply as discussed in the previous sections.
4. It would seem that the YAW displacement could be 3 inches each side of the longitudinal center line (same as side shift). It may be advisable to run some alignment tests using 40K loaders to verify this dimension.

4.4.1.2.6 Guide Rails. Military and CRAFT aircraft are configured for 463L ULDs which means all guide rails are set so they can accept the 108 inch wide x 88 inch long pallet. Other guide rail widths include:

- C-17 aircraft will have 88 inch guide rail width.
- Commercial airlines main deck rail guide widths are 88 inches and 96 inches.
- ISO Air/Surface Intermodal Containers are 96 inches wide.
- ULD Containers are 60.4 inches wide or 88 inches wide.

Issue:

Should guide rails on ATL be provided for 60.4 inch, 88 inch, and 96 inch spacing?

Discussion:

- 96 Inch Width - All cargo has to go on military or CRAFT aircraft. 96 inch wide containers, ULDs, etc., have to be mounted on 463L pallets to interface with the aircraft configurations. There would

be no advantage in setting guide rails at 96 inches to receive cargo coming off the aircraft at 108 inches.

- 88 Inch Width - The C-17 will have two sticks of pallets oriented so that the guide rails are set at 88 inches. The loader must accommodate this configuration.
- 60.4 Inch Width - The loader is required to service lower lobes of widebodied aircraft. LD Containers are 60.4 inches wide - the loader needs guide rails set at 60.4 inches.

Recommendations:

1. Configure the guide rail system on the ATL, which will accept and guide pallets, ULD containers, etc., at 108 inch spacing, 88 inch spacing and 60.4 inch spacing.
2. A common complaint on existing loaders is that rails are not rugged enough and get bent, causing misalignment of pallets. Rails should be designed to withstand impact loads anticipated with 60,000 lb. cargo.

Consideration:

Consideration can be given to an adjustable rail system and a remove and repositionable rail system. The adjustable rail system does not seem feasible because of the range of movement required.

4.4.1.3 Restraint Locks. Pallet restraint locks are required to lock each 463L ULD in position against loads imposed during transport or other modes of operation of the loader. These locks must be designed to:

Recommendation:

- Provide positive locking engagement thus, eliminating possibility of disengagement due to vibration or any other forces to be experienced by fully loaded pallets and platforms during operation of the loader.
- Be incorporated as part of the rail system or integrated into the loader deck.

- Be accessible and easily actuated at any deck height position.
- Be designed to withstand acceleration and deceleration loads of the largest load (60,000 lbs.) during loader operation.

4.4.1.4 Tie-Down Rings. Tie-down rings are required to secure cargo such as LD containers, which cannot be restrained by the restraint locks and in some instances to assist the restraint locks.

Recommendations:

- Review cargo restraint needs and select number of rings required and rated capacity of each to withstand acceleration and deceleration loads experienced during operation of the loader.
- Tie-down rings must be accessible at any deck height position.
- Tie-down rings should be incorporated as part of the deck structure and located to insure accessibility for restraining all cargo ULDs and rolling stock.

4.4.1.5 Deck Safety Features. Because of the additional load and height requirements associated with the ATL, certain safety features already incorporated in existing cargo loaders have even more significance. The following sections will provide a brief review of deck safety features and recommendations pertaining to these features.

4.4.1.5.1 Catwalk. The 40K loaders presently in use are equipped with a catwalk mounted on the left side of the deck, which provides side access to the entire length of deck. This catwalk can be removed and stowed upon the deck for air shipment of the loader.

Discussion:

With the size of load and the height to which the ATL is raised, it is apparent that changes will have to be made in the deck/catwalk design. The

restraint locks and tie-down rings must be accessible from both sides of the deck. The size and type of cargo require more stringent alignment procedures and the use of a spotter on the right side of the deck could well be required. The heavier loads, when and if required to be manually transferred, naturally require the use of additional manpower, and work space must be provided.

Recommendations:

- It is recommended that catwalks be provided on both sides of the loader in order to allow access to the entire length of the deck. This will increase the width of the loader but compromise between the width of the individual catwalks can be made. This requirement has been previously recognized because the 40K loader adapter, which enables the loader to reach B-747 deck height, currently provides for catwalks on each side.
- Structural requirements of catwalks should be determined based on maximum personnel and equipment loads.
- Constraints on overall width must be considered for catwalks on each side of the ATL, (See Section 4.4.3.2.2).

4.4.1.5.2 Handrails. It is recommended that:

- Handrails be provided along the entire length of each side of the deck and at each end of the catwalks.
- The access opening for cargo at each end of the deck and any access openings be protected with a safety chain, which can easily be removed when the access opening is to be used.
- Handrails be easily removable and capable of being stored on the loader for air transportability.
- That handrails be structurally adequate in conformance with OSHA Standards.
- Handrails be constructed of steel for ease of repair.
- Handrails be easily removed or repositioned for lower lobe and side-loading operations.

4.4.1.5.3 Deck Ladder. The deck ladder will be required to provide access from the ground level to any height to which the deck can be raised.

Recommendations:

It is recommended that:

- The deck ladder be a multi-sectional telescoping or folding ladder to automatically allow access from ground level through the entire range of deck travel.
- The ladder shall comply with appropriate OSHA standards.

4.4.1.5.4 Tread Surfaces.

Recommendation:

It is recommended that:

- All horizontal deck surfaces constituted as walk areas be covered with a non-skid coating or shall be constructed of non-skid material.

4.4.1.5.5 Emergency Stops. Emergency stops must be located at each end of the deck. The purpose of these stops is to prevent conveyORIZED loads from accidentally going off the end of the deck.

The utilization of the emergency stops used on the current 40K and 25K loaders is indicative of the type stop required.

Recommendation:

Design of stop should be predicated on the acceleration of a 60,000 pound load moving at maximum speed due to pitch of the deck or from transfer speeds.

4.4.1.6 Side-loading Capability. Side-loading (and end-loading) capability are provided on the latest 25K loader specification for forklifts by tine troughs. This capability is provided for the important loading/unloading

interface between forklift and the K-loader. There are other MHE and ATL loading interfaces which require a side loading capacity for the ATL.

Discussion:

- 463L Pallets are transported on B-747's with either the 108 inch or 88 inch side parallel with the aircraft's restraint rails. With the 88 inch orientation, pallets must be off-loaded with a first K-loader, then off-loaded onto a special transfer dock, rotated 90⁰, then on-loaded onto a second K-loader for transfer into the terminal system, which accepts only the 108 inch orientation.
- The limited maneuvering space provided at main deck side cargo doors for the B-747 and DC-10 has been outlined in Section 2.3.1.1. With side-loading capability, the ATL could serve as an elevating bridge, transferring pallets to other MHE, which can take advantage of the maneuvering space to the starboard side of the ATL. This procedure requires a first and single alignment of the ATL at the cargo door and substantially reduces the potential hazard for aircraft damage by eliminating the repeated requirement for ATL/aircraft alignment.
- The C-17 logistics system accommodates two sticks of 463L pallets with the 88 inch orientation. If a pallet rotation ramp is not provided on the aircraft ramp, an omni-directional transfer dock will be required.
- CHE specifically designed to top-load container/shelters will interface with the ATL for final transfer for aircraft loading (or unloading). Clearance for these CHE will be required for the load transfer function.

Recommendation:

It is recommended that the ATL provide starboard side-loading capability for MHE and ULD's as follows:

1. Forklifts: 10K - 463L Pallet
- Airdrop Platform
2. K-Loaders: 25K - 463L Pallet
40K - 463L Pallet
Trailers - 463L Pallet
3. CHE: ISO Containers/Shelters

Observations:

- The side-loading transfer system should be located as rearwards as possible to maximize available maneuvering space for interfacing MHE
- Deck handrails and catwalk shall be required to be removed or relocated to allow MHE access to the side-loading transfer system.
- For top-loading CHE, clearance from the starboard side (for container handlers) and on both sides (for straddle cranes) need only be considered.

4.4.1.7 Powered Deck. Neither the 25K and 40K loaders nor the TAC loader are provided powered conveyor systems on the cargo deck. The latest 25K loader specification requires a powered deck. The requirements criteria for the powered deck were no doubt based on safety and efficiency considerations.

A powered deck feature for the ATL is an important requirement for the following considerations:

- The higher load weight (60,000 pounds) will require more manpower for load transfer than previously required for 25K and 40K loads. Even with catwalks recommended on both sides of the deck, available workspace for loading personnel (in the number required) is limited.
- Use of the deck pitch function to accelerate loads is a hazardous exercise with loads of lesser weight than 60,000 pounds.
- Once in motion, there is a minimal control of the load by manpower executing the transfer.

With a powered deck:

- Ingress/egress of load handling personnel is limited to access to tie-down restraint locks and tie-down rings located on the sides of the load. Access by catwalks and protection by handrails have been recommended on both sides.
- Better load control can be executed by proportional control of both acceleration and deceleration (braking).
- Better efficiency is achieved by minimizing the number of personnel required for load handling.

- Operational safety is increased by minimizing the number of personnel on the elevating deck and minimizing the exposure to moving loads and minimizing, if not eliminating, the need for personnel to work on the roller deck surface.

Recommendation:

It is recommended that the ATL have a powered conveyor system for load transfer and control.

Observations:

Powered deck should provide:

- Receipt and discharge at both ends of conveyor
- Pallet stacking capability; move one pallet load singly.
- Deceleration and acceleration control.
- Drop-out or free wheel capability when disabled.

4.4.2 Operator's Cab

Appendix C contains a detailed sample task analysis and design recommendations for the operator's cab. These recommendations are summarized here.

4.4.2.1 Workspace. Key geometric and dimensional cab features are contained in paragraph 3.1 of Appendix C. These recommended cab clearances and measures accommodate 90% of the USAF male and female population. These recommendations are contained in MIL-STD-1472C.

4.4.4.2 Controls/Displays.

Recommendations: See Appendix C.

4.4.2.3 Seating. Seating design recommendations for both dimensions and clearances are contained in Appendix C. Additionally, in consideration of prevention of fatigue stress induced during long working/driving periods, attention should be given to ride quality. Of particular concern is the cab oscillation and vibration resulting from hard chassis suspensions.

Recommendations:

1. See Appendix C.
2. Provide seating system per Requirement 207, MIL-STD-1180.

4.4.2.4 Visibility. Visibility from the operator's vantage point must provide an unobstructed visual field when the ATL is operated (1) in the transport mode (as a ground vehicle) and (2) in the loading/unloading mode (aircraft interface). HFE criteria for ground vehicles as contained in MIL-STD-1472c, specify that operator visibility provide a forward visibility through a lateral visual field of at least 180° and a ground view at all distances beyond 10 feet in front of the vehicle.

For the loading mode, the operator's line of sight must be adequate to provide full view of the front end of the ATL deck and aircraft opening. In the elevating mode, the operator must have full overhead view of the area above the ATL deck and cab.

Recommendation:

- Operator visibility should be established on the basis of HFE criteria as contained in MIL-STD-1472C, MIL-HDBK-759.
- Requirements for rearview mirrors should be established per MIL-STD-1180.

4.4.2.5 Deck Location. The requirement to relocate the cab from a loading position to an air transport position is apparent. The air transport width of 111 inches cannot accommodate a cab and still provide for 108 inches of cargo width.

Lower lobe loading capability suggests a third location. Referring to Figure 2-38, the stand-off dimension from the 25K loader cab to the CLL deck surface is 26 inches. Reposition of the cab rearward, would allow the deck to fully interface with the aircraft fuselage. An alternative method is a retractable or collapsible bridge. This adds length to the deck, which is already compromised due to maneuvering limitations behind the aircraft wing on both the B-747 and DC-10 for the CLL. The repositioned cab is the viable alternative; except, of course, for the bridge device described in Section 2.1.4.1.

Recommendation:

- It is recommended that the ATL have a power-assisted cab for alternate positions for transport mode, lower lobe mode and air transport mode.

Observations:

1. The manually positioned bridge is obviously less costly. It's subject to be misplaced, damaged and potentially hazardous in handling.
2. The power-assisted cab provides versatility, with minimal manpower requirement and the ability to perform main deck and lower lobe loading functions alternately, with no assist requirement from personnel or MHE.

4.4.2.6 Cab Ingress/Egress. The observation is made in Appendix C, that ingress/egress to the 40K loader operator's cab is difficult and hazardous. This is the case with the deck in the elevated position. No walkway or standing surface is provided for the operator in entering or exiting the cab.

AFOSH Standard 127-66 requires that the operator remain in the cab during loading/unloading operations. An emergency situation or power failure will require operator to exit the cab with the deck in an elevated position.

Recommendation

It is recommended that the operator's cab include an easily-exited access panel door on the rear of the cab, with walkway and/or standing surface to provide safe egress.

4.4.3 Chassis

4.4.3.1 Unladen (Curb) Weight & GW. In Section 4.3, the maximum unladen weight of the vehicle was established at 60,000 pounds. This maximum limit was established on the basis of the air transport load criteria. It is a cursory analysis, which attempts to establish the maximum achievable vehicle weight with an acceptable longitudinal c.g. When considered as a road vehicle, the dynamic stability and dynamic axle loads are a function of c.g. location.

In turn, dynamic performance of the vehicle (tractive effort, braking, etc.) are influenced. The complete task of optimizing the vehicle configuration, wherein air transport and vehicle dynamics constraints are traded-off, will require a detailed design/development effort. There is no apparent reason to conclude that a 60,000 pound capacity ATL with 60,000 pounds curb weight cannot be achieved with state-of-the-art technology. Use of vehicle component weights reduction measures and high strength alloys steel could possibly affect a loader vehicle weight.

Recommendation:

1. Unladen (air transport) weight: 60,000 pounds
2. GFW: 120,000 pounds

4.4.3.2 Configuration. In this section we will more closely try to narrow down the configuration of the ATL. Until the USAF writes the specifications and design is initiated there will be many unanswered questions, but at least we can begin to narrow down some of the limits based on constraints discussed in earlier sections.

4.4.3.2.1 Length. The length of the existing 40K loader (5 pallet capacity) is 497 inches or approximately 42 feet. In Section 4.4.1.1 it was observed that to go to a 6 pallet capacity would increase the length of the loader to approximately 49 feet. Summarizing known constraints on length we get:

Summary:

- 40K Loader is approximately 42 feet long (5 pallets).
- ATL with 6 pallet capacity would be approximately 49 feet long.
- 49 foot is too long and would make servicing of B-747 and DC-10 aircraft hazardous because of clearance between wing and loader (Section 4.4.1.1).

Discussion:

Reviewing Figure 2-41 (B-747 cargo door clearance) it will be noted that the dimension from the door sill to the Number 1 flap wing fairing is approximately 50 foot. The length of the 40K (42 foot) is approximately 5 feet longer than the cargo load (37.3 feet). Using the same rationale, the length of a proposed ATL with a 40' cargo length would be approximately 45 feet. A 45 foot ATL would allow the loader to stop and raise the deck when 5 feet from the cargo door as required by USAF Standards (Ret. AFOSH 127-66 Chapter 12, Section 12.22b), however, there would be minimal clearance between the rear-end of the ATL and the flap wing fairing. If the standards were reviewed and the USAF decided to relax the 5 foot from aircraft requirement to say 3 foot, a 45 foot ATL would appear to be the maximum acceptable length.

Observation:

Length of ATL should be less than 45 foot based on minimum clearance requirements for aircraft.

4.4.3.2.2 Width.

A number of constraints and dimensional factors affect the overall operating width and air transport width of the ATL, not the least of which is the width requirement for air transportability. Referring to Section 2.3.1 and 2.3.2, the limiting constraints are as follows:

- Air Transport Mode: Allowable vehicle width for the C-141B is 111 inches; allowing 6 inch clearance on each side of the rear cargo ramp opening for vehicle maneuvering.
- Operating Mode:
 1. Opening between the petal doors on the C-141B for level loading of cargo is 203 inches; however, curvature of the doors above the door edge decreases with height above the ramp level.
 2. Specifications for straddle cranes will provide for an inside clearance dimension of 168 inches.

Observations:

- Overall width of the 40K loader at the front end (from cab left side to right side handrail) is 155 inches. The upper left corner of the operator's cab has minimal clearance when interfaced with the C-141B loading ramp.
- Width of the 40K loader behind the operator's cab (from left side handrail to right side handrail) is 140 inches.
- A recommendation for a catwalk on both sides of the ATL deck is made to insure personnel access to cargo restraints and for safe working area.

Discussion:

Allowing 6 inches of clearance, on both sides of the ATL for straddle crane clearance, limits the width of the ATL to 156 inches across the deck (behind the operator's cab). On the basis of the 40K loader (140 inches width) 16 inches are available for the addition of a catwalk on the right side of the deck. The addition of 16 inches to the width increases the overall width across the front end (including the cab) to 171 inches.

Recommendation:

1. It is recommended that the overall operating width of the ATL be no greater than 171 inches (across the forward end including the cab). Width across the deck (behind the operator's cab) shall be 156 inches from handrail to handrail.
2. It is recommended that the overall width of the ATL be reducible to 111 inches for air transport.

4.4.3.2.3 Height.

The critical height dimension for the ATL is the height of cab and handrails above the deck. This dimension is relevant for interface of the ATL with the ramp opening of the C-141B and C-130. To insure adequate overhead clearance for the ATL, height limitations must be related to the width limitations listed in Section 4.4.3.2.3 as the following:

- Overall width at the cab (forward end) has been identified to be 155 inches, i.e., the cab left side must be within 85 inches of the longitudinal center line of the deck.
- The height of the cab above the deck on the 40K loader is 32 inches.

- The hand rail on the right side of the ATL (allowing for a 16 inch catwalk) will be within 78 inches of the longitudinal centerline of the deck.
- Hand rails per MIL-STD-1472C shall be 42 inches high.

Recommendation:

1. It is recommended that the height of the operator's cab above the ATL deck be within 32 inches, with the cab side door with 85 inches of the deck longitudinal centerline.
2. It is recommended that height of the right side handrail be within 42 inches of the catwalk surface and positioned within 78 inches of the longitudinal centerline of the deck.

Observations:

1. Assuming the same deck height in the road (mobility) mode as the 40K loader (49 inches), overall height of the loader will be 91 inches at the handrails (81 inches at the operator's cab).
2. Overall height of the ATL in the lowest working height (39 inches) will be 81 inches (at the handrails) with a loaded ISO container (96 inch height), overall height will be 135 inches.

4.4.3.2.4 Ground Clearance.

Observation:

The ground clearance for the 40K loader under normal operation is 7-1/2 inches. This would seem to be adequate for service at a strategic airfield which is flat with no major obstructions. The requirement to self climb a 15° ramp in order to be transportable on the C-141 may affect wheel base and other criteria to reflect an improved ground clearance.

4.4.3.2.5 Approach/Departure Angle.

Observation:

The approach/departure angle (overhang clearance) is determined by the overhang (front or rear) of a vehicle. If the overhang is excessive, the vehicle cannot traverse steep grades. In the development of the ATL, the requirement to self-load on the C-141 up a 15° ramp would appear to be the constraint.

4.4.3.2.6 Wheelbase (Axle Spacing).

Observation:

When the designer of the ATL considers wheelbase (axle spacing) requirements, there are two considerations to be made.

- Wheelbase requirements for the transport mode of operation.
- Wheelbase requirements in order to comply with air transportability requirements.

The air transportability will be the determining factor in design.

4.4.3.2.7 Suspension (Axle Articulation).

Observation:

The suspension and axle articulation design will be a function of, and predicated on, the requirement for air transportability.

4.4.3.3 Mobility. In this section, the maneuverability and mobile requirements for the ATL will be explored.

4.4.3.3.1 Speed and Gradeability.

AFOSH 127-66, Chapter 12, Section 12.22b requires that K-loader speed be limited to 5 MPH in the vicinity of aircraft and 10 MPH on rams. Top speed of

the 40K loader (fully loaded) is 15 MPH forward and 5 MPH in reverse on level grade, with a sustained forward speed of 12 MPH on a 3% grade. These maximum speeds are adequate for the ATL, there being no requirement for increased speed. This limited speed also improves road stability for the higher GVW of the ATL.

Recommendation:

1. Maximum speed when fully loaded (120,000 lbs. GVW) is recommended to be no greater than 15 MPH forward and 5 MPH in reverse.
2. Sustained speed on a 3% is recommended to be 12 MPH forward and 3 MPH in reverse.

4.4.3.3.2 Traction. The ATL is required to be capable of traversing a 3% grade in a tractive environment resulting from rain, snow, sleet, ice, sand, and mud on a prepared surface. Multi-driven axles will be required, with slip differential or individually driven wheels.

4.4.3.3.3 Inching Capability. With loads of this size and with the accuracy of alignment required, infinite adjustment of the loader as it approaches the aircraft is desirable. The use of a high torque low-speed drive system is a reasonable way to achieve this requirement.

4.4.3.3.4 Turning Radius (Clearance Radius). The turning radius of a vehicle is the radius of the arc described by the track of the outermost forward tire while turning a corner at maximum steering (cramp) angle. Although turning radius is essential in defining the maneuverability of the ATL, it is the clearance radius of the ATL, which must also be defined to insure that the ATL is capable of maneuvering in the limited area available when servicing the

main side cargo door of the B-747 and the CLLs of the B-747 and DC-10. The clearance radius is the radius of the arc described by the outermost projection of the ATL when turning a corner at maximum steering angle. The turning radius of the 40K loader is 40 feet. The ATL will operate in the same aerial port environments as the 40K loader and should be expected to have equal or better maneuverability.

Recommendation:

1. Clearance radius of the ATL is recommended to be no greater than 50 feet, with a turning radius of 40 feet.

4.4.3.3.5 Emergency Shutdown. In a motorized vehicle of this type carrying large loads and operating in the close proximity of an aircraft, the need exists to shutdown all movement in case anything goes wrong, it is essential the ATL be equipped with a "kill" switch button or other device. The button should be within easy reach of the operator, so that actuation will shutdown all systems.

4.4.3.3.6 Standby Emergency Operation. Malfunctions or failure to operate the ATL cannot under any circumstances capture the aircraft (i.e., prevent the aircraft from being used). It is necessary that a power standby system to power all circuits be provided. Such a system must be capable of operating on both internal and external power sources.

4.4.3.3.7 Maintenance Accessibility. Provisions must be made to gain accessibility to all components of the ATL for maintenance purposes. In the case of engines, transmissions or drive trains, which may be located in areas which are obstructed when the deck is down, the standby emergency system must be capable of moving the deck and/or other components so that accessibility is possible.

4.4.3.3.8 Braking. Although the ATL will not be used in a regulated highway or system, its mobility and maneuverability capability and the traffic environment in which it will operate is equivalent to a regulated system. It is recommended that the braking system of the ATL comply with the requirements of MIL-STD-1180, Federal Motor Vehicle Safety Standards and Federal Motor Carrier Safety Regulations.

4.4.4 Stability - Wind Loading

The ATL will be capable of transporting and lifting a 60,000 pound load 18 feet, 6 inches off the ground. During the last five feet of approach to the aircraft, the loader will be moving (albeit slowly) with loads of this magnitude at full height. Consideration must be given to the stabilization of the loader during this phase of the operation and when aligned with the aircraft. Stabilization systems may be required. Items to be considered which affect the stability include:

- Wind Loads: The loader must be able to withstand wind loads of some defined magnitude when servicing the aircraft with a 40 foot container acting as a sail some 18 feet in the air. The magnitude of wind load, the allowable side movement (sway) which will not damage the aircraft, and the stabilizing resistance to overturning moment must be defined.

- Stability: When actuating deck alignment functions as discussed in earlier sections, the impact on the shifting of the C.G. must be determined and the ATL stabilization be effected to withstand the overturning moment.
- Transport Stability: Stability in the transport mode must be considered in conjunction with turn radius, speed and GW center of gravity.

Stability is a safety issue. Aside from transport stability, which for all practical purposes is road stability, there are two very important stability modes:

1. Approach Stability: That period in which the loader is traversing the last five feet for alignment with the aircraft with a fully elevated load. The wheel tracks and the C.G. of the loader must be sufficient to prevent overturning of the loader.
2. Operational Stability: This is the period during which the loader is servicing the aircraft. The wheel track and C.G. of the loader must still be capable of preventing overturning of the loader. But, in order to obtain a minimization of side movement (sway) due to operational loading and wind loads, stabilizing devices such as outriggers may be employed.

Both approach and operational stability will be adversely influenced by high winds. Use of the loader during high wind conditions can result in damage to the loader and the aircraft and injury to personnel. It is necessary to determine the maximum wind conditions under which the loader is expected to service aircraft so that this requirement can be integrated into the final design.

Recommendation:

It is recommended that a stabilizing system (stabilizing jacks and/or outriggers) be incorporated into the ATL design:

- To insure that initial positioning of the ATL deck with aircraft decks is achieved and maintained within the limits of deck alignment functions i.e., pitch, roll, side shift and yaw) for final deck alignment.
- To provide stability and structural rigidity during critical cargo transfer operations (from ATL to aircraft and vice versa).

4.4.5 Structural Integrity

The designer of equipment is always faced with the reality that he does not control the elements that constitute a final product. In order to compensate for variations in material strengths, occasional overload conditions and other factors which, only through experience, can be anticipated he rely's on a factor of safety. The purpose of the safety factor is to minimize the risk that the working stress to which a member is subjected will exceed the strength of the material.

For most calculations the factor of safety is defined as:

$$f_s = \frac{S_m}{S_w}$$

in which:

f_s = factor of safety

S_m = yield strength of the material (psi)

S_w = allowable working stress (psi)

In general S_m is based on yield strength for ductile materials, ultimate strength for brittle materials and fatigue strength for parts subject to cyclic stressing.

4.4.5.1 Design Factors. Based on yield strength, structures of this type are usually designed to provide a static safety factor of 2 to 1.

4.4.5.2 Nuclear Certification. Based on yield strength, structures which handle nuclear loads are usually designed to provide a static safety factor of 3 to 1 or a dynamic safety factor of 2 to 1.

- Since it is recognized that the largest nuclear load to be handled by the ATL will not exceed 20,000 pounds, the 60,000 pound load rating for the ATL with appropriate safety factors will be most conservative for handling nuclear loads.

4.4.6 Self Transport

There is no requirement for the ATL to transport another identical loader. The rated load and the unladen weight (60,000 lbs) of the loaders are compatible for self loading. Other interfaces will need to be investigated, i.e., tire footprint on deck, wheelbase loading, and compatible tracking interface.

4.4.7 Towing Capability

There is no requirement for the ATL to tow other vehicles or MHE. No other MHE or vehicle is designed to be towed by the ATL for cargo handling operations.

4.4.8 Climatic Conditions

In Section 2.2.2 weather/environmental conditions to which the ATL will be exposed were discussed. Basically, it is anticipated that the ATL can be used anywhere in the world and be subjected to the full spectrum of environmental

influences one would anticipate for such service. Reference was made to MIL-STD-210 as a helpful guide to uniform climatic design criteria.

4.4.8.1 Temperature Range. Specifications as defined for K-loaders are anticipated to be compatible with the development of the ATL. Temperature ranges are as follows:

Operational Range: -40°F to +140°F ambient

Storage Range: -60°F to +160°F ambient

4.4.8.2 Salt Air/Water. Examples were given in Section 2.2. of corrosive environmental locations where the K-loaders are exposed to high humidity and salt spray environment. It is anticipated that the ATL will function as designed when subjected to the salt/spray environment as defined by appropriate military specifications (MIL-T-5422).

4.4.8.3 Humidity/Moisture. It is anticipated that the ATL will be operated in environments which contribute to a high moisture and humidity exposure. Appropriate military specifications should be utilized to define the humidity/moisture constraints imposed the ATL design (MIL-T-5422).

4.4.8.4 Fungus. It is recommended that to the greatest extent practicable, the materials used in the ATL shall be non-nutrients for fungi. Appropriate military specifications should be utilized to define the fungi restraints (MIL-T-5422).

4.4.9 Nuclear, Biological and Chemical Protection and Electromagnetic Pulse Protection

Nuclear survivability is the capability of a system to perform its defined function after exposure to specified levels of nuclear weapons effects (EMP and blast, thermal and initial radiation effects). The intent of equipment survivability is to ensure that equipment remains operational if enough personnel remain effective after exposure to an enemy nuclear attack. This need is dependent on the criticality of mission completion after a nuclear attack or where it can be replaced before its absence becomes critical to mission completion.

Survivability after NBC attacks is usually provided for combat weapons systems and command communications systems.

The need for nuclear survivability for the ATL obviously must be established. The total population of ATLs and their capability for air transport suggest that equipment and personnel protection measures be resolved in a post-nuclear environment and actual post-chemical and biological agents attacks. The personnel protection measures and EMP protection measures in Section 2.2.4 are recommended.

4.4.10 Reliability, Availability, Maintainability and Dependability

Availability of 90% is the standing MAC directive for all MBE. Levels between 85%-90% are maintained. The basis by which this level is established and the means and measures employed to maintain this level require scrutiny. The 90% level maintained is for peace-time, non-surge usage. Using the equation for availability from Appendix B ($A = T_o + T_s / T_o + T_s + T_d$), an availability of 0.9 requires a total available time, $T_a = T_o + T_s = 21.6$ hours and down-time $T_d = 2.4$ hours for an average 24 hour period. Yet maintenance personnel

interviewed at bases surveyed stated the same problematic theme, i.e. long lead times for repair parts and the need for constant repair to K-loaders, because of frequent failures. This would seem to be inconsistent with an availability of 0.9. The explanation is more likely that the low usage rate yields high failure rate is really based on actual operating time, i.e. the unit's fail frequency when used. This speculation seems to be confirmed by the results of the MHE Surge Test compiled at Pope AFB (See Appendix B). Total MTBF was 15 hours.

The long lead times for replacement parts is also inconsistent with the 90% availability. Lead times in the logistics network, are measured in weeks and months. It could mean that failures requiring long lead time components are infrequent, but more likely means that replacement parts are obtained, if available, outside the system, directly from commercial sources.

The observation made in this study is that availability of 90% is maintained marginally with difficulty and commensurate cost. The logistics network may be seen to support the 90% availability, but largely due to resourceful enterprise of maintenance and logistics personnel by going outside the logistics network.

The same conclusion that several previous investigations have made is concurred. During contingencies, when required, operating time will increase as much as ten-fold, availability will decrease markedly to levels of 50-60%.

In Appendix B, the relationship between dependability, availability, reliability, and maintainability is developed in detail.

The salient point made in Appendix B, is the obvious one. The probability that a stated mission be completed (load/unload a given number of aircraft with a known cargo tonnage) is a function of availability, which is largely a

function of reliability, maintainability, and availability of spares/replacement parts. Recommendations are made as to the means to achieve established levels of reliability, maintainability and parts availability. The important ingredient is availability, which must be first determined. Given the availability, reliability and maintainability indices can be determined and program plans developed, which provide that up-front design considerations be taken to insure they are achieved with development of a logistics network to insure that they are maintained at the design levels.

The potential MTBF of a new loader is estimated in Appendix B to be 60 hours. Using GIDEP data and non-electronic parts reliability data, the MTBF for an equivalent 40K loader was determined. The relevance of the estimate is that state-of-the-art components and technology is available to achieve that level of reliability.

Section 5

EVALUATION

In Section 4.0, the performance requirement(s)/ parameters for the ATL are established. The rationale for the recommended performance requirement(s) parameters was based on performance capability, operational efficiency, safety or HFE factors. There can be negative effects for reliability, maintainability, supportability and cost. A further evaluation, which considers all of these factors, is included in Table 5-1, page 5-8 of this section. The evaluation provides a marginal analysis of the ATL as compared to the cargo handling system's existing MHE. The recommended performance requirement(s)/parameters were considered for an ATL which performs the entire mission. Its total functional capability was established on the basis that it perform the total loading/unloading function for all aircraft while interfacing with all elements of the 463L system. The basis for the mission definition is that it replace all aircraft loading/unloading MHE. Therefore, an evaluation of the ATL's recommended performance requirement(s)/parameters is properly made in a comparison with the system's current aircraft loading/unloading MHE, which includes the K-loaders, elevator loaders and lower lobe loaders.

Factors evaluated in the analysis include the following:

- P - Performance Capability
- E - Operational Efficiency
- S - Safety
- H - Human Factors (includes safety and efficiency)
- R - Reliability
- M - Maintainability
- I - Supportability (ILS)
- L - Life Cycle Cost

Further, it was recognized that requirements and parameters considered singly in Section 4.0 should be grouped because in combination they provide a single functional capability or have a casual-effect relationship. For this reason primarily, and for ease of presentation they were grouped as follows:

1. Capacity
 - Capacity (ULDs) - para. 4.4.1.1
 - Capacity - Rolling Stock - para. 4.4.1.1.1
 - Elevation (Deck) - para. 4.4.1.2.1
2. Yaw Capability - para. 4.4.1.2.5
3. Load Securing
 - Guide Rails - para. 4.4.1.2.6
 - Restraint Locks - para. 4.4.1.3
 - Cargo Tie-Down Rings - para. 4.4.1.4
4. Side Loading Capability - para. 4.4.1.6
5. Powered Deck - para. 4.4.1.7
6. Cab
 - Workspace - para. 4.4.2.1
 - Controls/Displays - para. 4.4.2.2
 - Seating - para. 4.4.2.3
 - Visibility - para. 4.4.2.4
 - Location - para. 4.4.2.5
 - Access Panel - para. 4.4.2.6
7. Air Transportability
 - Curb Weight - para. 4.4.3.1
 - Configuration - para. 4.4.3.2.1 thru 4.4.3.2.7
8. Mobility - para. 4.4.3.3.1 thru 4.4.3.3.4
 - Curb Weight - para. 4.4.3.1
9. Stability - para. 4.4.4.4
10. Climate Conditions - para. 4.4.8

The methodology used for the evaluation is to assign a numerical value for each evaluation factor to estimate the relative impact or effect each recommended functional capability has on the evaluated factor. The estimated numerical value is based on a score assigned on a scale of 0 to 10. The selection of the score is judgmental and relies upon the collective summation of inputs derived from previous sections. This is a systematic process whereby the evaluating team has collectively assigned values based upon knowledge of the system and practical experience with similar equipment systems. Scores assigned for each evaluation factor for each functional capability for the ATL are also based and assigned on the relative score assigned for the system MHE.

A weight factor is assigned to each functional capability. This ranking of functions indicates the relative ranking assigned by the evaluation team in establishing the importance and relevance to mission completion by the ATL.

Total scores for each functional capability are determined as follows. A numerical score is assigned (estimated) for each evaluation factor for each functional capability. The numerical average of the evaluation factors is multiplied by the weight factor for the functional capability to arrive at the total score for the functional capability for both the ATL and MHE.

Two criteria used in assigning evaluation factor scores are as follows:

1. An increased functional capability is achieved by the ATL with similar equipment systems. For example, the added deck height to 18 ft. 6 inches is accomplished with a hydraulically actuated grasshopper lift mechanism similar to that currently used on the 40K Loader. New functional capabilities are evaluated on the basis of conceptualization as contained in the appropriate section.

2. Scores assigned to the support related factors (i.e., Reliability, Maintainability, ILS and Life Cycle Cost) are estimated on the basis that the ATL is developed with a program similar to that of the existing MHE. The assumption made is that no tailored development plans, similar to those recommended in Appendicies A, B and C are incorporated. This basis for evaluation is believed to give a better estimate of the factors for the ATL as compared to the MHE.

The rationale for estimating and assigning scores to each functional capability are as follows:

1. Capacity: The value of 10 for both Performance and Efficiency follow from the increase in load capacity (60,000 lbs) and maximum elevation height (18 feet, 6 inches). Of the existing MHE, only the elevator loaders and 40K Loader with deck adapter can reach the wide-bodied aircraft deck heights. And both are limited to 40,000 lbs or less. The lower scores for safety and HFE for the ATL AC knowledge the increased height and capacity of the ATL over either the Elevator Loaders or 40K Loader. For each of the support factors, R, M, I, and L, the ATL is estimated to be higher in that the ATL can have equal or higher reliability than the 40K Loader with maintainability and logistics support being necessarily higher by virtue of the fact that the ATL will ultimately replace these units with commensurate improvement in reliability, maintainability and logistics. Life cycle cost for a single ATL should be better (less) than the associated cost of supporting a multiplicity of units.
2. Load Securing: Load securing systems for the ATL should have substantially improved performance and efficiency if for no other reason than that the inadequacy of current systems on the 25K and 40K Loaders are removed. The recommendation for tie-down rings for the ATL provides that they be made more accessible and be incorporated for both the identified ULDs and specified rolling stock. No effect on safety or HFE is to be anticipated. In addition, catwalks and handrails have been recommended on both sides of the deck for safe and efficient access to the restraint locks and tie-down rings. Reliability, Maintainability and ILS are scored lower than the MHE in

acknowledging that the restraint locks and tie-down systems may be required to be more complex and costly to overcome the deficiencies of the existing systems on MHE. Life cycle cost should be improved on the basis of a single unit for the air cargo system.

3. Air Transportability: The higher scores for the ATL for Performance, Efficiency, Safety and HFE reflect a vehicle that meets the recommended performance as contained in Section 2.3.2. The lower scores for Reliability, Maintainability and ILS anticipate that the axle suspension system, the drive system and axle articulation will be more complex than that currently utilized on the 25K or 40K Loaders. The equal score for Life Cycle Cost is based on a trade-off of current system costs, primarily due to the elevator loaders, with reduced cost to support the single unit system.
4. Stability: The stabilizing system recommended for the ATL is a new system capability for which there is no basis for comparison with current MHE, except for the inherent stability that the MHE has. The higher scores for Performance, Efficiency and Safety follow logically from the added capability realized for the critical ATL/aircraft alignment function and stability inherent in rigidizing the ATL deck during loading/unloading operations. Reliability, Maintainability, ILS and Life Cycle Cost score lower on the basis that a new functional equipment system is added.
5. Cab: The substantiation for the higher score for Performance and Efficiency is two-fold. First, a power-assisted, relocatable cab minimizes the time required for repositioning the cab from main deck to lower lobe operating positions. There is no need for manual handling. The same is true for repositioning for the air transport mode. HFE recommendations made in Appendix C are directed to improving operator efficiency and minimizing human error and increasing safety. The complexity of the overall cab system necessarily acknowledges that the system will be less reliable, more difficult to maintain and support unless special consideration be given to development programs directed at insuring adequate levels.

Life cycle cost can increase accordingly.

6. Mobility: Recommendations for mobility related performance requirements have not substantially provided increased capability over that currently included in the 40K Loader. The clearance radius recommendation for 50 feet and the inching capability may require more complex systems than currently included in the 25 and 40K Loaders. Maneuverability and mobility required for air transport are the primary reason for the higher Performance, Efficiency, Safety and HFE scores. The lower scores for R, M, I and L follow for the same reason.
7. Climatic Conditions: Incorporation of systems to improve ATL performance and efficiency in a broader spectrum of environmental conditions can erode the reliability and maintainability of the ATL, particularly for systems designed to insure and improve performance in the more severe and adverse environmental conditions (i.e., cold temperature, contaminants, humidity, moisture, etc.). Performance, efficiency, safety and HFE can be improved by incorporating appropriate equipment systems, but attention must be given, during the development phase that such systems have designed-in reliability, maintainability and ILS. The scores assigned for these factors reflect anticipated values, as compared to existing MHE, without such considerations being made.
8. Side Loading: The recommendation for side loading for the ATL is made to insure that the ATL have the capability to interface with all MHE which must load/unload the ATL. These MHE are the forklifts, CHE and other K- and elevator loaders. In addition to providing this interface capability, side loading increases the versatility of the ATL by adding the capability of allowing it to serve as a loading bridge for the same interfacing MHE. The highest score is assigned for Safety, since the side loading capability removes the hazard associated with loading ULDs from the side. The higher scores for Performance, Efficiency and HFE follow from the capability to interface with all side loading MHE, which current MHE do not have.

Addition of a new subsystem for side loading can result in reduced reliability, maintainability and ILS with commensurate increase in Life Cycle Cost.

9. Powered Deck: The advantages of a powered deck have been listed in the appropriate paragraph in Section 4.4. The primary reason for a powered deck is the added safety realized when transferring loads of maximum rating for the ATL (60,000 lbs). Loads of that magnitude would be difficult, if not impossible, to handle on an elevated deck with limited access by the number of personnel required to move the load. The high scores for Performance, Efficiency, Safety and HFE follow accordingly. Complexity of the system requires a lower score for the support factors.
10. Yaw Capability: A yaw capability is not absolutely necessary for the loading/unloading function. Efficiency, Safety and HFE are the primary factors which justify the recommendations. Although performance is improved, the relative score is less than that, for example, for the side loading and powered deck function. Although lower scores are assigned for reliability, maintainability and ILS and cost, these need not be lower if the side shift function equipment is utilized for the yaw capability.

EVALUATION RESULTS

One could have speculated that the calculated scores for the ATL would be higher than those for the MHE, and it would be difficult to argue knowing the possible prejudice that may be present. In fact, all but the stability, mobility and climatic conditions scores of the ATL were higher than the MHE scores. These scores may be fortuitous, but before looking for some significance in the numerical scores, and their difference, it is relevant to review the rationale applied in assigning the scores.

Of the ten (10) functional capabilities evaluated, five are new or added functional capabilities not currently contained with the MHE family. These include Stability, Cab, Side Loading, Powered Deck and Yaw. Although not new

Table 5-1 Evaluation

Evaluated Factors

<u>Functional Capability</u>	(W.F.)	P	E	S	H	R	M	I	L	TOTAL
1. <u>Capacity</u>	(10)									
ATL		10	10	6	6	8	8	8	9	81
MHE		6	7	8	8	7	7	7	6	70
2. <u>Load Securing</u>	(10)									
ATL		9	9	9	8	7	7	7	8	80
MHE		4	6	9	9	7	9	9	7	75
3. <u>Air Transportability</u>	(10)									
ATL		10	9	8	8	6	7	6	7	76
MHE		7	6	7	7	8	9	8	7	74
4. <u>Stability</u>	(10)									
ATL		9	9	10	7	7	6	6	7	76
MHE		7	7	7	5	9	10	10	9	80
5. <u>Cab</u>	(9)									
ATL		9	8	9	9	7	6	6	6	68
MHE		5	6	7	6	7	8	8	8	62
6. <u>Mobility</u>	(8)									
ATL		8	9	8	8	9	7	7	7	63
MHE		6	7	8	8	9	9	9	9	65
7. <u>Climatic Conditions</u>	(7)									
ATL		9	9	8	6	6	6	6	6	49
MHE		7	7	8	8	8	8	8	8	54
8. <u>Side Loading</u>	(6)									
ATL		9	9	10	8	7	6	7	7	47
MHE		4	5	5	6	9	10	10	9	44
9. <u>Powered Deck</u>	(6)									
ATL		9	9	9	9	6	6	7	7	47
MHE		0	0	6	6	10	10	10	10	39
10. <u>Yaw Capability</u>	(5)									
ATL		8	8	9	9	7	7	7	8	40
MHE		5	5	6	6	8	10	10	10	38

or added capabilities, the Air Transportability, Capacity and Mobility functional capabilities are significant improvements over those currently contained in the existing equipment. Load Securing and Climatic Conditions are recommended on the basis of inadequacy in the current system.

The rationale used in assigning relative scores acknowledged that in each case either a new equipment subsystem or an improved performance, equipment subsystem would be required to achieve the recommended performance requirement. Accordingly, the anticipated or recognized complexity of the new systems, although justifying the higher scores in performance and efficiency, also recognized the potential for degradation in the support factors, namely, reliability, maintainability, ILS and LCC. Similarly, the evaluation made allowance for the better, but still unsatisfactory rating in the support factors for the existing MHE, while being penalized for the deficiencies in performance and efficiency and safety and HFE, where identified.

If there is any significance to the evaluated score, it is that in most instances, the ATL scores are higher or comparable, even after a deliberate assessment for degradation in the support factors. The conclusion to be made is that the recommended functional capabilities, which are intended to obviate and eliminate the deficiencies of the family of MHE as a whole, will affect an ATL which will ultimately replace all aircraft loading/unloading MHE. But, the development of the ATL must provide for full scale consideration for the support of the ATL, i.e., with reliability, maintainability and logistics support which will guarantee that it replace these MHE with lower life cycle cost.

The scores calculated for the ATL are higher than those for the MHE, except for the functional capabilities for stability, mobility and climatic conditions. The differences in score, for these three, is not substantial, but

a review of the detailed scoring does shed some light on the reasons for the lower scores for the ATL.

The increase in performance, efficiency and safety gained by the stability system on the ATL are insufficient to offset the loss of support factors. In other words, the elevator loaders and X-loaders have an inherent stability resulting from the structural design and/or chassis suspensions provided. They do not have a stability system, per se (such as outriggers/jacks), specifically designed or developed for increased stability. For this reason, scores assigned for R, M, I and LCC are perhaps disproportionately high. These higher scores evaluate the inherent stability of these MHE as opposed to a dedicated stability system. Therefore, R, M, I and LCC are not adversely affected.

The same comments can be said for the mobility and climatic conditions scores. In brief, stability, mobility and climatic conditions capabilities, and equipment required to achieve improved performance, efficiency, safety and HFE are evaluated to be more sensitive to the performance/efficiency vs. support factors trade-offs considerations.

Section 6

DEFICIENCIES AND RECOMMENDED SOLUTION

Deficiencies found in the military air cargo system fall into three categories which for the sake of explanation shall be designated as functional capabilities deficiencies, RAM & ILS deficiencies and failures/malfunctions.

6.1 FUNCTIONAL CAPABILITIES DEFICIENCIES

These relate to the MHE in the system, particularly the K-loaders, and elevator loaders. The deficiencies for the most part are limited capability of each type of unit. As has been too obvious, the K-loaders have insufficient range to reach the main decks of wide-bodied aircraft. This short fall in performance was filled by the elevator loaders. But they have limited application. They access only the main deck, not the lower lobe deck. The same is the case with the lower lobe loader, it serves only lower lobes and narrow bodied aircraft. The result is many pieces of equipment, none of which can do the total job. The performance/ requirement(s) parameters for the ATL have been evaluated and recommended on the basis of doing the total loader mission. This is the merit of this study and evaluation, i.e., although not immediately, the ATL will eventually replace all the current loaders, except for the TAC loader. Certainly, there are other considerations such as cost and schedule. But for performance deficiencies, the ATL would seem to be the solution. It should be noted that whereas the 40K loaders have a performance

deficiency when compared to the total system, they are not deficient with regard to their design specification. Special deficiencies observed for the loaders are as follows:

40K Loader:

1. Capability limited to 40,000 lbs.
2. Limited to deck height of 13 ft.
3. Cannot handle ULD's longer than 5 pallet lengths.
4. Cannot reach into lower lobes without a bridge.
5. Cannot properly guide and restrain (lock) ULD's other than 108 inch width.
6. Is air transportable on C141B and C5 but require shoring and winching and a commensurately long preparation time and loading time.
7. Cannot be side-loaded from forklift or other K-loader.

All of these are performance shortcomings which will ultimately be eliminated by the ATL. The same is true of elevator loaders:

1. Cannot service lower lobes.
2. Cannot service all system aircraft.
3. Capacity limited to 40,000 lbs.
4. Cannot handle ULDs longer than 3 pallet lengths.
5. Is air transportable, but requires assisting MHE, palletizing, and requires 8 hours preparation time.
6. Has very limited mobility.

There are no apparent solutions to the performance deficiencies, at least no short-range, which can "fill the gap" before an ATL is fielded. The time-consuming and labor intense adapters and bridges must fill the gap.

6.2 RAM AND ILS DEFICIENCIES

These problems can best be described as "poor state of repair" problems. The elevator loaders and 40K loaders are worn-out, particularly the elevator loaders. The deficiency is predominant in reliability. These units have been worked excessively and the inherent reliability is inadequate for the usage rate expected in the MAC system.

6.3 MALFUNCTIONS/FAILURES

These are not deficiencies, per se. As inputted in surveys and workshops, by maintenance personnel, they could be taken as the typical type found with usage of automotive and hydraulic equipment.

6.4 SOLUTIONS

Consideration could be given to remanufacture and/or modification to resolve the performance deficiencies. But such an approach, if possible, would likely trade-off one capability against another. It is not likely that any of these loaders can be modified for increased capability. Increased deck height or deck length would increase the structure weight and likely require a reduction in rated capacity.

Viable solutions which should be considered are as follows:

1. Remanufacture and modification of the elevator loaders. Provide reliability, maintainability and ILS programs as an integral part of the program.
2. Remanufacture and modification of the 40K Loader, with integral reliability, maintainability and ILS programs.

Section 7

CONCLUSIONS

Recommendations for the performance requirement(s)/parameters for the ATL have been detailed in Section 4 with accompanying rationale and commentary.

In arriving at these recommendations, both commercial and military air cargo handling systems have been reviewed, with an in-depth review of the USAF air cargo handling system to ascertain the total mission definition or "role" of the ATL in the system. In so doing, the requirements for the ATL have been established on the basis that the ATL perform the complete loading/unloading function for all military and commercial aircraft in the system while interfacing with all elements of the 463L system. Some key observations and conclusions, which influenced the final definition of performance requirements, have been made and are summarized here.

7.1 COMMERCIAL VS. MILITARY SYSTEM

Commercial air cargo systems are based largely on the Just-In-Time concept of material delivery. As a result of this concept, timely delivery of air cargo from the delivering aircraft to the consignee is affected by minimizing the aircraft parking distance from typically highly automated terminals, which are characterized as having a full complement of material handling equipment, both fixed and mobile. As a result of this terminal design, commercial aircraft loaders are usually designed to serve as loading/unloading bridges, which transfer cargo from the aircraft directly to the air cargo terminal or to other cargo transfer equipment. For this reason maneuverability and

mobility of the loaders is minimal, there being no requirement to transfer heavy cargo consignments over large distances from aircraft to terminal.

In the military air cargo system, aircraft loaders perform the dual function of transporter and loading bridge. Military aircraft are often parked a considerable distance from the terminal, if one exists, or to staging areas from which concluded transit of cargo takes place. Greater distances are traveled by the military aircraft cargo loaders, over terrain requiring both highway and limited off-highway capability. The key element in this operational scenario is the transport element. This performance capability distinguishes the military aircraft loader from the commercial loader. Several basic performance characteristics result from the role of the ATL in the 463L System and the military airlift mission. These bear mentioning since they have a significant bearing in determining its performance capabilities:

1. 463L Capability: The 463L System is well established and will continue to influence the selection and development and design of the cargo type configurations, material handling equipment, aircraft systems and terminal facilities used in the system. The 463L System is a roller-conveyor system and all systems used must address this basic ULD handling concept. The 463L System is a successful well-established approach and will continue to dictate air cargo handling methods well into the next century, until such time that a more efficient, cost-effective cargo handling system is developed.
2. Transporter-Loader Concept: To be both effective and efficient in the 463L System and the MAC Airlift System, the ATL must be a multi-purpose, self-sufficient aircraft loader. Operating scenarios for the ATL require that it perform its function of servicing all system aircraft with minimal assistance from other elements of the material handling family.

3. Air Transportability: Readiness and availability to operate at any location within the military air cargo handling system requires the ATL to be air transportable with minimum preparation time (2 hrs) without the need for loading, shoring or assistance by other MHE.

7.2 BASIC ATL CONCEPT

Characteristics of the physical elements of the USAF air cargo system suggest and indicate a leading candidate concept. This basic concept for the ATL is a self-propelled, diesel-powered, hydraulically actuated vehicle, with an elevatable roller-conveyor cargo bed, with tractive effort provided by axle driven pneumatic tires. This basic concept is the result of three primary characteristics of the system.

- 463L Compatibility - All the ULDs are designed or adapted for roller-conveyor systems. All aircraft, terminal and MHE systems are fitted with roller-conveyor systems.
- Support Systems - Maintenance and operating personnel, procedures and facilities are geared and in-place for this type of equipment.
- Air Transport - Axle and tire load limits of aircraft cargo compartments and ramps are most favorable for axle driven pneumatic tire vehicles.

7.3 PERFORMANCE REQUIREMENT (S)/PARAMETERS

The basic performance characteristics of the ATL and the resulting basic ATL concept have been seen to have a great influence in determining its detailed performance requirement/parameters. A summary of these requirements is contained in Table 7-1 to serve as a condensed reference. For each requirement/parameter contained in Table 7-1, paragraph sections in Section 4 of this report are listed for reference.

Table 7-1 Summary of ATL Performance Requirement(s)/Parameters (sheet 1 of 2)

	<u>RECOMMENDATION</u>	<u>REF. PARA.</u>
Air Transportability:	C-141B, C-5, C-17	4.3
Capacity:	Cargo Weight - 60,000 lbs. Cargo Length - 40 Ft.	4.4.1.1
Deck Elevation:	39 Inches (Min.) 18 Ft. 6 Inches (Max.)	4.4.1.2.1
Deck Pitch:	<u>±</u> 6 Degrees	4.4.1.2.2
Deck Roll:	<u>±</u> 4 Degress	4.4.1.2.3
Deck Side Shift:	<u>±</u> 3 Inches	4.4.1.2.4
Deck Yaw:	<u>±</u> 3 Inches	4.4.1.2.5
Guide Rails:	108, 88 & 60.4 Inches	4.4.1.2.6
Restraint Locks:	60,000 lbs. Capacity	4.4.1.3
Tie-Down Rings:	60,000 lbs. Capacity	4.4.1.4
Deck Safety:	Catwalks Handrails Ladder Tread Surfaces Emergency Stops	4.4.1.5.1 4.4.1.5.2 4.4.1.5.3 4.4.1.5.4 4.4.1.5.5
Side-Loading:	Forklifts CHE K-Loaders	4.4.1.6
Powered Deck:	Deck Front & Rear Acc./Dec. Control Drop-Out Provision	4.4.1.7
Operator's Cab:		
Workspace	MIL-STD-1472C	4.4.2.1
Controls/Displays	MIL-STD-1472C	4.4.2.2
Visibility	MIL-STD-1472C	4.4.2.3
	MIL-STD-1472C	4.4.2.4
Cab Location:	Relocatable for Air Transport and Lower Lobe Operations	4.4.2.5
Cab Emergency Egress/Ingress	Rear Access Panel	4.4.2.6

Table 7-1 Summary of ATL Performance Requirement(s)/Parameters (sheet 2 of 2)

	<u>RECOMMENDATION</u>	<u>REF. PARA.</u>
Curb Weight:	60,000 lbs.	4.4.3.1
GVW:	120,000 lbs.	4.4.3.1
Overall Length:	45 Ft.	4.4.3.2.1
Overall Width:	171 Inches (@ Cab) 156 Inches (@ Deck)	4.4.3.2.2
Overall Height:	91 Inches (Road Mode)	4.4.3.2.3
Ground Clearance:		4.4.3.2.4
Approach/Departure Angle:	Per C-141B Ramp Loading Requirement	4.4.3.2.5
Wheelbase:		4.4.3.2.6
Suspension:		4.4.3.2.7
Speed/Gradeability:	15 MPH Forward 5 MPH Reverse 12 MPH (3% Grade)	4.4.3.3.1
Traction:	Multi-Drive Axle Slip Differential	4.4.3.3.2
Inch Capability:	Low Speed - High Torque Drive System	4.4.3.3.3
Turning Radius:	40 Ft.	4.4.3.3.4
Clearance Radius:	50 Ft.	4.4.3.3.4
Braking:	MIL-STD-1180, FMVSS, FMCSR	4.4.3.3.8
Chassis Safety:	Emergency Shutdown	4.4.3.3.5
	Standby Emergency Operation	4.4.3.3.6
	Maintenance Accessibility	4.4.3.3.7
Stability:	Jacks/Outriggers	4.4.4
Structural Integrity:	2:1 S.F. (Static) 3:1 S.F. (Dynamic)	4.4.5
Climatic Conditions:	MIL-T-5422 -40° to 140°F (Operation) -60° to 160°F (Storage)	4.4.8
NBC:	EMP Protection Personnel Protection	4.4.9
RAM-D:	Appendices A & B	4.4.10

7.4 RELIABILITY, AVAILABILITY, MAINTAINABILITY AND DEPENDABILITY

Availability of 463L MHE has been reported to be maintained at 90%. Maintenance personnel at several operating bases have repeated the same problematic theme; long lead times for repair parts and constant repair of K-loaders because of frequent failures. This theme seems to be reinforced by a low MTBF of 15 hours. These observations raise the question of adequate availability during a sustained surge contingency.

The ATL as conceptualized here has been proposed to perform the total aircraft loading function of all existing MHE taken collectively. It is reasonable to assume that it will replace most of them. For this reason, the availability requirement for the ATL must be assessed for the totality of USAF airlift operational plans, both for peacetime and contingencies.

The presentation contained in Appendix B has shown the relationship between reliability, maintainability, and parts availability. To insure that the availability requirement for the ATL be realized and sustained through its service life, the acquisition plan should include the provisions for an ILS, Reliability and Maintainability Plan as outlined and recommended in Appendices A and B.

7.5 REPORT SUMMARY

The primary result of this study effort is the definition of performance requirements and recommendations for performance parameters for an aircraft transporter-loader. The result of this report can serve as an input to the development exercise for a performance specifications for an ATL. These recommendations have been developed for input to a development program for an ATL, which will ultimately satisfy the following objectives.

1. The ATL will perform the total mission of cargo transport to and from plus loading/unloading of all aircraft in the USAF air cargo system. It will interface with all elements of the system.
2. The ATL will function in the present USAF System, and future system. Its functional applicability will be sustained by the current and future use of the 463L system.
3. Air transportability requirements for the C-141B, C-5 and C-17 have been identified and will insure flexible of usage at all aeral port locations, which can receive these aircraft.
4. Reliability, Maintainability and ILS Program plans will be established to insure its availability to perform in the totality of airlift operations.
5. State-of-the-art components and technology are available to insure design and development of the ATL with reliability and maintainability performance, which will affect the required and improved availability for the ATL.

**Appendix A INTEGRATED LOGISTICS
SUPPORT PLAN**

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APPENDIX A

INTEGRATED LOGISTICS SUPPORT PLAN

1.0 INTRODUCTION

Integrated Logistics Support is being viewed today on a much broader scale and has been growing progressively, incited primarily by advanced technology, social trends and economic constraints. As technology advances, systems and products become more complex, increasing costs and the need for logistic support. Thus, logistics, which includes the integration of many design elements with maintenance and support activities has become significant in each phase of the system life cycle. Consequently ILS requirements are initially planned and integrated into the system design process. The bottom-line is to produce a system incorporating the necessary logistic support capability in an efficient and effective manner.

By acknowledging the U.S. Air Force Reliability and Maintainability Action Plan R&M 2000, the advanced aircraft loader of the future will incorporate elements of Logistic Support. The Logistic support package required for new system acquisition is based on the Department of Defense Directive 5000.39; Acquisition and Management of Integrated Logistic Support for System and Equipment. This Directive establishes the requirement for life-cycle management of major system ILS, updates policy and responsibilities for the acquisition and management of ILS programs as an integral part of the acquisition process, and provides guidance when establishing ILS policy for less-than-major systems and equipment. In essence this Directive states the requirement "That an acquisition program shall include an ILS program that begins at program initiation and continues for the life of the system". Using this directive as a guide, an ILS program is tailored to meet the requirements of support for an advanced aircraft loader. Figure 1 depicts the basic ILS considerations during the System Life Cycle and system development process of a new system. These ILS considerations are then used to develop an Integrated Logistic Support Plan (ILSP) that identifies the major areas of support and rationale.

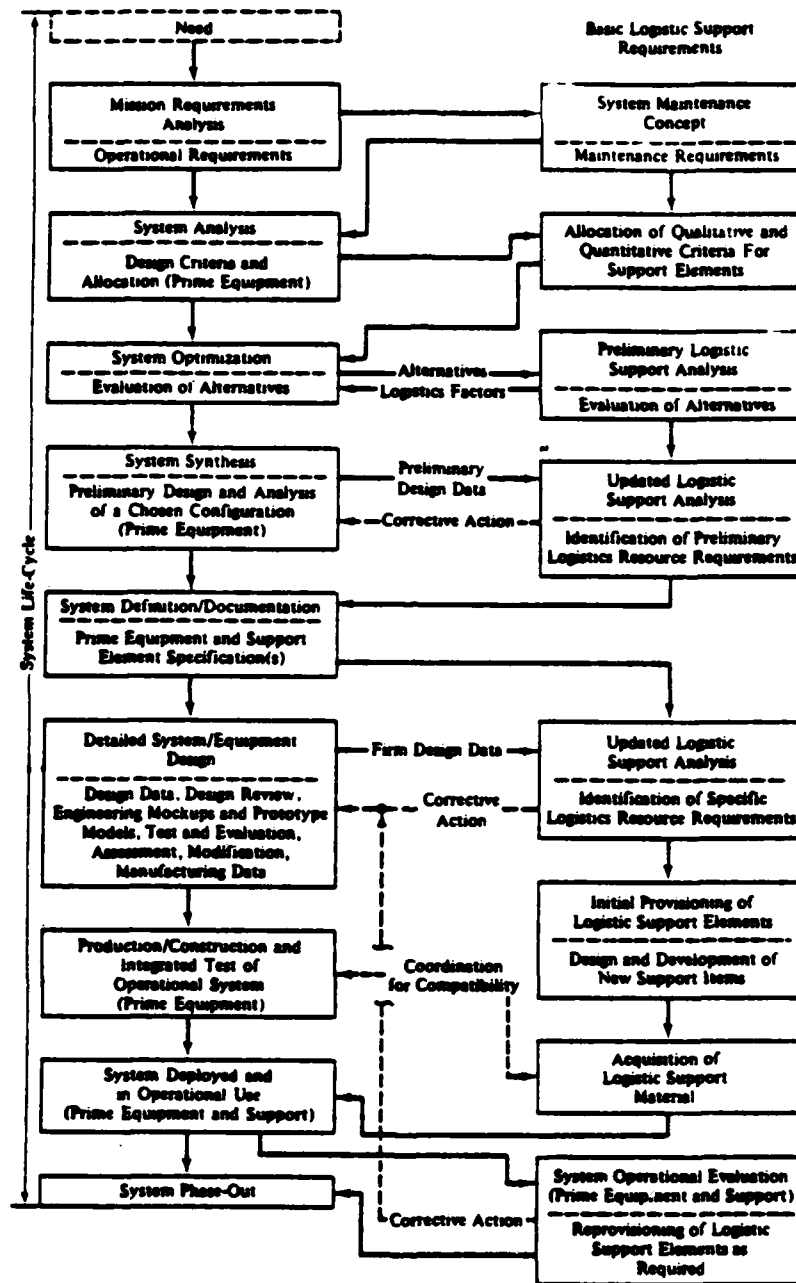


Figure 1 System Development Process

2.0 ILS PLAN

An Integrated Support Plan (ISP) presents the methodology for developing support management techniques, program controls, and task procedures for implementation on a new system acquisition. These management concepts, approaches, and support element functions to be implemented on this program are based on the criteria of Department of Defense Directive 5000.39, Acquisition and Management of Integrated Logistics Support for Systems and Equipment.

The ISP is prepared as the single controlling document providing guidance for implementing ILS considerations during design, development, production, testing, and fielding of the new system. The document is then written in a format, per contract SOW and/or applicable DID(s), that includes but is not limited to the following sections:

- Section I (Introduction)
- Section II (Summary of System Characteristics)
- Section III (ILS Program Management and Execution)
- Section IV (ILS Program Tasks)
- Section V (Milestone Schedules)
- Section VI (Related Plans)
 - A - Maintenance Support Plan
 - B - Logistics Support Analysis Plan
 - C - Training and Training Equipment Plan
 - D - Technical Manual Plan
 - E - Repair Parts Program Plan
 - F - Transportability Plan
 - G - Engineering Drawing Plan
 - H - Maintainability Program Plan
 - J - Mission Profile

The ISP, when government approved, is the controlling document for Integrated Logistic Support (ILS) of the Aircraft Loader. The ISP is revised and/or updated at government request or when impact has occurred to logistics element cost, schedule, and/or performance.

2.1 APPLICABLE DOCUMENTS

Below are documents on which an ISP can be based.

DI-L-30318	Air Force AFSC Integrated Logistics Support Plan
DOD 5000.39	Acquisition and Management of Integrated Logistics Support for Systems and Equipment, dated 17 January 1980
DI-E-6117	Engineering Drawing Plan
DI-L-7017	Logistic Support Analysis Plan
MIL-STD 1388-1A	Logistics Support Analysis
MIL-STD 1388-2A	DOD Requirements for a Logistic Support Analysis Record, Dated 20 July 1984
MIL-STD 1561	Provisioning Procedures, Uniform Department of Defense
MIL-STD 38784A	General Requirements, Technical Manuals

3.0 SYSTEM DESCRIPTION

This section of the ISP describes the overall system and subsystems of the advanced aircraft loader. In general, this system description identifies the systems ability to provide the necessary functions for which it was designed. Characteristics of the loader that should be clarified in further detail are, but not limited to the following:

- 1) Loader Subsystem
- 2) System Mobility
- 3) Speed/Acceleration
- 4) Stopping and Vehicle Control
- 5) Climbing, Traversing, and Vertical Abilities
- 6) Electrical System
- 7) Hydraulic System
- 8) Powerplant/Drive Train
- 9) Operator Station
- 10) Load/Unload Limits
- 11) Environmental Operations

4.0 OPERATIONAL PARAMETERS

This area describes the system requirements specified by the Air Force and the design specification developed by engineering. This includes operational needs, modes, and transition abilities before and after being transported.

5.0 RELIABILITY DESIGN REQUIREMENTS

These requirements will be developed by the Contracts Reliability Group and will include but are not limited to the following:

- 1) Acceptable mission liability based on Composite Mission Profile
- 2) Demonstrated Reliability
- 3) Level of confidence
- 4) Established reliability baseline for subsystems

This data will be incorporated into the ISP.

6.0 MAINTAINABILITY DESIGN CRITERIA

One of the more important ILS design considerations is system maintainability. Advanced loader ILS elements shall address design characteristics dealing with the ease, accuracy, safety and economy in the performance of maintenance functions. Logistics disciplines assure that methods and techniques are detailed and defined to facilitate the maintenance process. Maintainability is being considered along with the performance, reliability, maintainability, producibility, supportability, life-cycle cost, and other factors in the system design. The overall ILS/Maintainability design influence goal is to ensure that design and system engineering are concerned with a loader system that can be maintained in the least amount of time, at the least cost, and with a minimum expenditure of support resources (e.g., personnel, materials, facilities, test equipment) without adversely affecting the system mission profile.

Maintainability/ILS considerations will interact with the other support system elements and system requirements formulated during the system design. The close relationship between maintainability and system support has a direct effect upon the system maintenance requirements. This fact shall be considered in the development of the qualitative and quantitative ILS consideration areas.

Hardware arrangement and mounting considerations can drive the desire to reduce overall support costs through a low-maintenance design concept. Through the Repair level Analysis (if required) the intent will be to identify high reliability, low cost items as candidate for discard.

7.0 MAINTENANCE CONCEPT

The maintenance concept is a series of statements and/or illustrations defining criteria covering maintenance levels, support policies, effectiveness factors (e.g., maintenance time constraints), and basic logistics support requirements. The maintenance concept is a prerequisite to system/equipment design and development.

The maintenance concept provides the basis for establishing supportability requirements in system/equipment design and requirements for total logistics support. The maintenance concept leads to the identification of maintenance tasks, task frequencies, task repair times, personnel and skill levels, as well as support equipment, spare/repair parts, facilities, and other resources.

8.0 ILS PROGRAM MANAGEMENT AND EXECUTION

The contractor should develop and implement an ILS program for the advanced loader based on Department of Defense Direction 5000.39 (Acquisition and Management of Integrated Logistics Support for Systems and Equipment) and/or other applicable documents. The management principles and techniques described in these documents shall be applied to the specific requirements of the loader program to ensure maximum availability at optimum support costs.

The discrete support elements, associated events, and management controls will provide a timely and adequate assessment of support requirements and ensure systematic analysis of design considerations to determine independent impact on each other.

Planned positive management actions, time phased to specific program events, will enable early integration of support criteria in associated design activities, thereby providing a credible technical basis for developing significantly improved life-cycle cost within the performance and availability requirements of the loader program.

8.1 GENERAL PURPOSE OBJECTIVE

The primary purpose/objective of the overviews, practices, and procedures is to ensure loader support elements meet contract requirements on or before scheduled delivery and within budget. In addition, they are to provide a framework within which to manage (plan, organize, staff, direct and control) the loader program throughout its entire life cycle and/or contract period in the most cost effective manner possible.

8.2 ILS PURPOSE/OBJECTIVES

The primary objective is to ensure the accomplishment of the aforementioned policies. Additional and related objectives are to:

1. Ensure that design effort reflects and includes logistics factors necessary to achieve minimum life cycle cost.
2. Ensure that loader development and production program provide timely availability of all logistic resources upon deployment of the system.
3. Define long-term support requirements at minimum life cycle cost.

8.3 ILS ORGANIZATION

The contractor should have an integrated management team dedicated to ensuring that ILS is optimized in the design, development, production, and fielding of the advanced aircraft loader. The following paragraphs describe an ILS management organization.

8.4 MANAGEMENT CONCEPT

A good Management Concept utilizes a matrix organization which draws upon the resources of the entire Engineering, Logistics and Product Support (LPS) disciplines. While key individuals from the various Engineering and ILS elements should be assigned full-time to the loader program, many others are utilized as their individual and specialized expertise is required. This Management Concept provides program management, directional stability, flexibility, enthusiasm, and a wide range of problem-solving ability.

9.0 ILS ORGANIZATION AND RESPONSIBILITIES

An example of a Logistics and Product Support Department (LPSD) is structured as an ILS project team (Figure 2) in direct relation to the support element functions. This enables effective administration of data and enhances inter/intra-departmental communications.

Interrelationships and resolutions of logistics problem areas are accomplished through an ILSM team concept, comprised of the ILSM as chairman, and a member from each of the logistics functional areas (Training, Logistics Engineering, Technical Publications, Spare Administration). Indirect support services are provided by budget plans and Computer Resources. Members of these logistics organizations should attend team meetings and assist in problem resolution as the need arises.

In an ILS organization each section is responsible for accomplishing assigned work tasks, establishing working interface with other disciplines, and collecting or disseminating data. Primary functional responsibilities of the ILS are as follows:

- a. Logistics Engineering Group - responsible for performing Life Cycle Cost (LCC) studies, Repair Level Analysis (RLA), and Logistics Support Analysis (LSA). The results of these studies/analyses are the primary source of information for developing other logistics data.

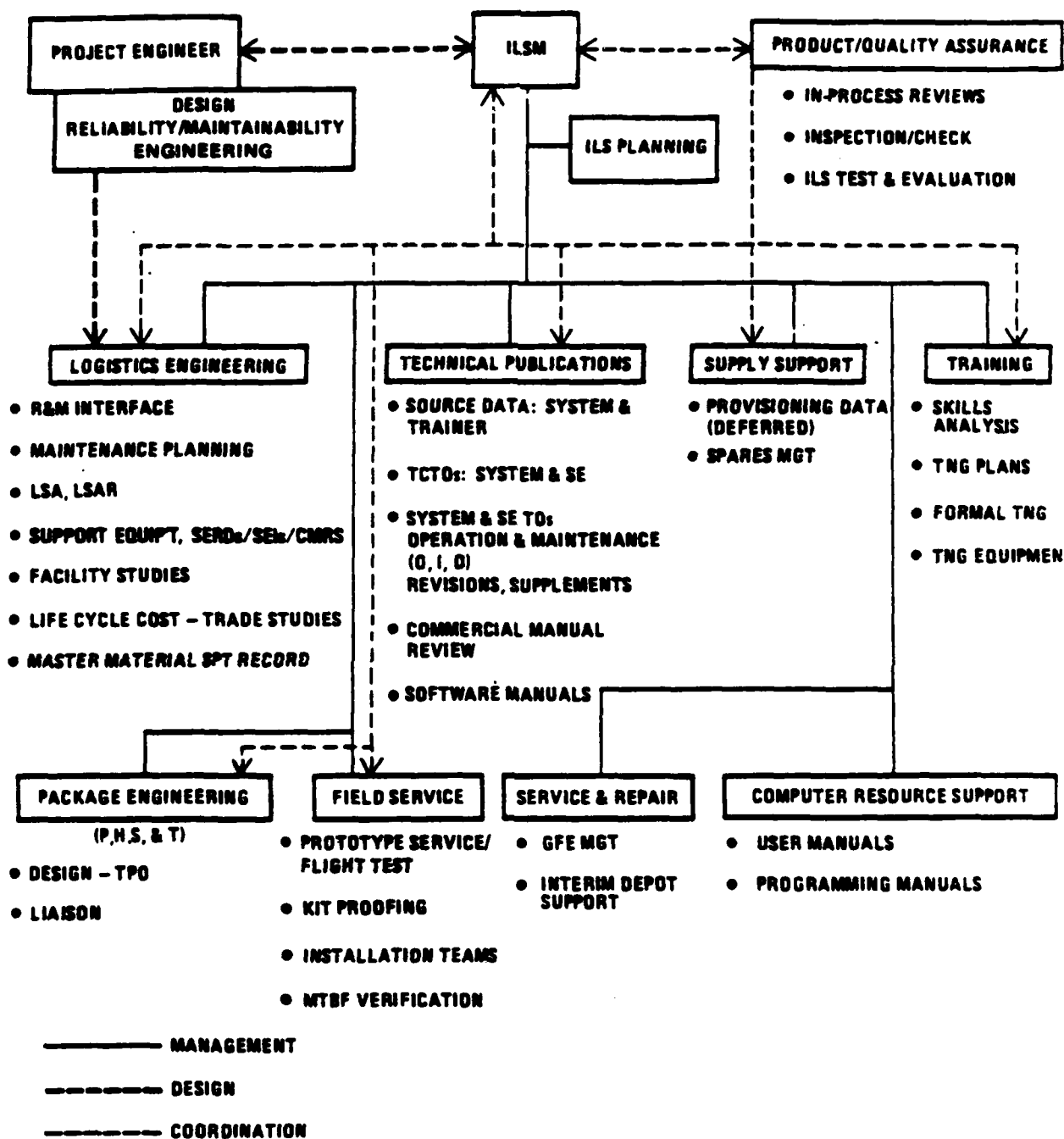


Figure 2 ILS Project Team

The Logistics Engineers maintain close liaison with Reliability, Maintainability and Design Engineering to define support requirements as they become known. Any design changes that impact logistics are documented through the LSA process to ensure compatibility throughout all logistics elements.

- b. Integrated Logistics Support Management Group - responsible for support requirements definition, developing maintenance and support plans, coordinating change requirements and spare assets, and costs control.
- c. Provisioning Documentation Group - responsible for spare requirements, provisioning documentation, provisioning conference activities, milstrip requisition, and Illustrated Parts Breakdown manuals.
- d. Technical Publications Group - responsible for all technical manuals, IPBs, T.O.'s, graphic training aids, engineering reports and technical manual/validation plans.
- e. Field Service Group - responsible for providing on-site installation, acceptance testing, and repair. Field Service Engineers provide maintenance assistance and follow on maintenance training as part of contractor services.
- f. Training Group - responsible for training of customer personnel. This group also controls and administers training requirements during the Operational Phase as required by the procuring activity.
- g. Configuration/Data Management Group - responsible for data management, configuration control boards, configuration status, engineering change proposals, contract data scheduled, engineering bills of materials and the Configuration Management Plan.
- h. Graphic Communications Group - responsible for blue prints, microfiche, printing, drawing release, photographs, and graphic aids.

- i. Package Engineering Group - responsible for packaging requirements, packaging drawings, packaging systems, packaging data, and Transportation Evaluation Reports, as required.
- j. Computer Resources Support Group - responsible for the development modification, and maintenance of ILS related software, data bases and ILS information management systems.

10.0 ENGINEERING CHANGE PROPOSAL (ECP) CONTROL PROCEDURE

The Logistics Eng/ILSM, as a member of the Configuration Control Board (CCB), reviews and analyzes the effect of engineering changes for logistics implications. The Log Eng/ILSM should provide a maintenance analysis of the technical aspects of any proposed change, and make recommendations as to the practicality of the change from a LCC and maintenance standpoint.

11.0 CONCLUSION

Logistic support for the advanced aircraft loader should be a major consideration in the establishment of system/subsystem requirements, development of design criteria and evaluations of alternatives leading to the selection of a resolute design configuration. The object is to develop a system that is fully supportable and will fulfill its mission at the lowest overall life-cycle cost.

**Appendix B RELIABILITY, AVAILABILITY,
MAINTAINABILITY AND SYSTEM SAFETY
STUDY AND EVALUATION OF CURRENT
AND FUTURE AIRCRAFT LOADERS**

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1.0 INTRODUCTION

A procurement for a new aircraft transporter-loader must contain reliability, maintainability, and system safety design requirements and statement of work tasks tailored to assure that the loader design and associated logistics support will permit achievement of operational objectives and minimize life cycle costs. From an operational point of view, availability and dependability requirements will drive the number of loaders required, spares requirements, and R&M requirements. Life cycle costs may cause additional adjustments to the R&M requirements. The next two sections will discuss reliability and maintainability problems with the current loaders, recommended design techniques, and the program task needed to assure that the new loader will meet its requirements. The next section will discuss dependability and availability models and requirements, and their impact on the R&M requirements, spares, and number of systems required. The last section will describe system safety problems, design criteria, and needed tasks.

2.0 RELIABILITY

The loader must be able to reliably handle specified loads and perform other specified functions without damage to itself, the cargo, or the equipment with which it is interfacing. Many of the problems identified in the study could be eliminated by fully specifying the operating environment in which the loader is to be used together with adequate analyses and testing to assure that the design will operate and survive in the specified environment. As a minimum, the environmental specification should include the following:

- Temperature extremes
- Sand and dust
- Rain
- Shock and vibration (road conditions included)
- Special conditions such as concurrent loading and aircraft refueling

In addition, the design must eliminate failures due to internally induced environmental factors and loads.

Specifications for the new loader should contain a mean time between failure (MTBF) requirement for the loader system which is consistent with availability and life cycle cost requirements. Th MTBF includes only those maintenance actions due to malfunction and does not include maintenance actions due to scheduled maintenance and periodic inspections, although the latter does impact maintenance indices and availability.

2.1 EXISTING 40K AND 25K LOADERS RELIABILITY PROBLEMS

Loaders in the current inventory have exhibited a number of reliability problems which should be eliminated in a new design. The problems identified during the study together with their possible causes are listed below. For the most part, specific design solutions have not been indicated since the causes may not be well understood and because the contractor should be responsible for solving the problem in the most cost effective manner possible after analysis and study.

- (a) The open flame cabin heater and defrost are ineffective and unsafe when operating near an aircraft.
- (b) The cabin window handles, regulators, and latches fail, and windows are frequently broken. Vibration appears to be a factor in regulator and latch failures.
- (c) The cabin seat design is weak and fails in an unsafe manner. Failures may be caused by vibration and shock. It has a very harsh ride.
- (d) Radiator lines, metal hydraulic lines to the engine, hydraulic reservoir, and the suspension fail frequently. The likely causes are vibration and shock.
- (e) Steering system failure due to shock (potholes) and when turning at low speeds or stopped.
- (f) Rails bent, decks warped, and columns bend under load.

- (g) Differentials fail when traction regained after slipping on ice and snow.
- (h) Transmission fails too often.
- (i) Hydraulic lines to cabin fail due to flexing. They should be eliminated and electrical controls substituted.
- (j) Hydraulic failures probably caused by overheating of the system.
- (k) Exposed electrical and mechanical parts fail due to moisture, dirt, and debris.
- (l) Pallet stops are undependable.
- (m) Low battery causes diodes to burn out on circuit boards.
- (n) There are wide variations in the reliability of different engines and other subsystems. Reliability should be a major factor in the selection of off the shelf subsystems.
- (o) Toggle switches in the cabin are frequently broken.
- (p) The power winch distribution pulley is ineffective causing line kinks and tangles.
- (q) Ladder wears at slide guides and binds.
- (r) There is no means of controlling shutdown of hot engines.
- (s) Hydraulic tank and system leak excessively.
- (t) Means should be provided to insure proper drainage of moisture from all components.
- (u) Bushings and bearings wear excessively.
- (v) The exhaust system points downward and blow excessive dirt, dust and debris into engine and hydraulics systems.
- (w) Dust filters are inadequate in heavy dust environment.
- (x) Excessive engine RPMs are required to maintain deck position when off loading aircraft.

2.2 RELIABILITY DESIGN REQUIREMENT CONSIDERATIONS

Reliability requirements must be consistent with the established availability/dependability requirements and life cycle cost considerations. The requirement must also be achievable and capable of being clearly demonstrated. The stated requirement should be the result of tradeoff studies between the number of units at each base, maintenance indices, quantity and

types of spares, and the overall system dependability required. An approach to developing the relationships between these factors will be discussed in the section on availability and dependability. The reliability requirements must support the stated maintainability requirements.

It is recommended that the reliability requirements be stated in terms of required mean time between failure (MTBF) and that the MTBF be demonstrated in the field. The field MTBF should be specified since there is often a wide disparity between predicted MTBFs based on design analyses or those demonstrated in the laboratory type tests. However, predictions are an extremely valuable tool in assessing the system design early in the program and for determining the inherent reliability of the system. Differentiation should be made between mission critical failure and maintenance and series MTBF. The maintenance MTBF takes into account all failures and is used to evaluate maintenance indices and life cycle costs. The mean time between critical failure (MTBCF) only considers those failures which render the loader unuseable, and may allow degraded modes of operation within well defined conditions. The MTBCF also accounts for redundancy in design.

The potential MTBF of a new loader design was investigated by estimating the MTBF of the current 40K loader based on its illustrated parts breakdown. Government Industrial Data Exchange Program (GIDEP) replacement data and the Nonelectronic Parts Reliability Data published by the Reliability Analysis Center were used in the estimate. The only change made to the parts list was to eliminate the current cab heater and replace it with an electric heater. The estimate was compared with the results of the MHP Surge Test compiled by Pope AFB. The Test data was purged to eliminate line items known or suspected to be scheduled or inspection maintenance actions. The carburetor and ignition systems were also deleted since they would not be used in a system using

diesel engines. Where no failures were observed, an MTBF equal to the total operating hours was assumed for comparison. The results are summarized in Table I. Because the test data does not follow the technical order parts breakdown, some line items are not common to both the test data and the estimated MTBF. However, most of the subsystems with the major failure rates appear in both columns. As can be seen, the existing loader could be expected to achieve an MTBF of about 60 hours. A new loader design could be expected to achieve an MTBF in the range of 100 to 200 hours provided that an effective reliability program is implemented and that performance requirements do not significantly impact the complexity of the loader. The analysis performed indicates that the complexity of the loader, especially of the hydraulic system and hose installation, has a significant impact on the reliability. It is recommended that the achievable reliability of a new loader be studied further in order to determine the cost of design and development versus system effectiveness and life cycle costs.

2.3 RELIABILITY DESIGN TECHNIQUES

In order to improve reliability in a new loader, it must be considered during the design phase of the program. Some techniques which can be used to assure a reliable design are outlined in this paragraph.

System design tradeoffs must consider the relative reliability merits of one design approach versus another. These tradeoffs would include such items as use of gasoline versus diesel engines, air brakes versus hydraulic brakes, selection of the heater/defrost design approach, etc.

The criteria for selection of off-the-shelf subsystems and components must include reliability. The components/suppliers selected should have a proven field reliability in the environment specified or be able to extrapolate from

Table 1

SUBSYSTEM	CURRENT MTBF	ESTIMATED MTBF
Engine	380	1130
Cooling system	270	3310
Fuel system	720	1410
Charging system	340	
Exhaust system	1310	3870
Electrical system	150	3020
Starting system	620	3390
Clutch	28950*	
Heater/booster	340	20000
Transmission	530	1050
Brakes	600	570
Steering	360	2920
Suspension	2410	
Universal Joints	7240	
w/S wipers	4140	14900
Differential	970	4220
Hydraulic system	160	530
Air system/brakes	270	1410
Speedometer	930	38460
Control cable	2410	
Turrets	28950*	
Hose reel/rewind	28950*	
Valves	2630*	
Meters/counters	28950*	3970
Nozzles	28950*	
Swing joints	28950*	
Piping water/fuel	28950*	
Foam c-b	28950*	
Pump system/hoses	28950*	
Hydraulic Cylinders		1160
Cargo Deck/Trays		330
Hoses/Cables Instl.		310
Other	40	1970
Total system	15	60
System w/o Other	20	60

a related environment. System reliability requirements must be allocated to subsystems or components and included in purchase order and subcontracts.

All components must be adequately derated. The derating criteria for applicable mechanical components such as the engine and hydraulic subsystem must contain thermal considerations as well as mechanical limits.

The loader must include adequate thermal designs for the electrical/electronic, engine, and hydraulic subsystems to insure that certain criteria and high reliability are achieved.

Electrical and electronic parts and connections must be protected from moisture, corrosion, and contamination.

Mechanical moving parts must be protected from dirt, dust, and debris where excessive wear, jamming, and corrosion would impact component life and system reliability.

Secondary failure modes (failures caused by another failure) should be eliminated.

Common items such as nuts, bolts, resistors, capacitors, semiconductors, etc., should be MIL-SPEC parts.

Components should have multiple sources to the maximum extent possible.

The loader must be designed to prevent collection of moisture and contaminants. Where it is impossible to prevent debris collection, a fast, simple method of removal should be provided.

The design must minimize the complexity of the loader and hydraulics interconnections.

2.4 RELIABILITY PROGRAM

A reliability program, documented in accordance with MIL-STD-785B, is a proven means of assuring that reliability goals and objectives are met.

The tasks should be selected and tailored for the type of system being designed. As a minimum, the following tasks should be performed:

- (a) Task 101 - Prepare reliability program plan
- (b) Task 102 - Monitor/control of subcontractors and suppliers
- (c) Task 103 - Program and design reviews
- (d) Task 104 - Failure reporting, analysis and corrective action system
- (e) Task 105 - Failure review board
- (f) Task 201 - Reliability modeling
- (g) Task 202 - Reliability allocations
- (h) Task 203 - Reliability predictions
- (i) Task 207 - Parts program
- (j) Task 208 - Reliability critical items
- (k) Task 209 - Effects of functional testing, storage, handling, packaging transportation, and maintenance.
- (l) Task 301 - Environmental stress screening
- (m) Task 303 - Reliability qualification test

In addition, Tasks 204 (Failure modes, effects and criticality analysis) (FMECA) and 302 (Reliability development/growth test) are strongly recommended. The tasks are described in MIL-STD-785B and will only be discussed here in terms of tailoring to the loader.

Details of the FMECA requirements and techniques are described in MIL-STD-1629A. This analysis is very useful as a tool in maintainability analysis, system safety analysis, and in identifying critical failure modes with respect to performing the mission. The latter makes this analysis almost indispensable if a mean time between critical failure has been specified and must be predicted.

As discussed above, the reliability prediction should be performed using field data to the maximum extent possible for off-the-shelf equipment. Predictions for unique design should be based upon a design analysis of parts application, the intended environment, and applied stresses. MIL-HDBK-217D should be used for new electrical/electronics design.

2.5 RELIABILITY TEST PROGRAM

A reliability qualification test must be performed on the loader at the end of the development phase to insure that reliability requirements have been achieved in the design. Field tests should be performed in the actual intended use environment and conditions. All modes of operation should be exercised. The test should be designed to insure statistical confidence in the results. Minimum acceptable MTBF should be specified in addition to the design or required MTBF. A test plan from MIL-STD-781C may be specified provided that wearout failures are not induced by excessive test time on any one unit. Following the MTBF demonstration, the test may be continued on one system until a specified time has been accumulated to evaluate the life and wearout characteristics of the loader.

An environmental stress screening test (burn-in) should be conducted on all loaders prior to delivery to the customer. The purpose of the test is to force failures due to workmanship, bad parts, and quality control. It serves to insure that the reliability of the loader is maintained during production. This test should be conducted on a road or surface designed to simulate actual conditions and should insure that all modes of the loader are exercised.

A reliability growth test is recommended. The purpose of such a test is to identify design weaknesses and correct them during the design and development phase. The test is usually run using the same environmental conditions as specified for the reliability qualification test. Although it may be run using simulated conditions, it is recommended that the test be performed in the field prior to the reliability demonstration. It is desirable to integrate the two tests for cost and schedule reasons. This may be accomplished by adding the time required for the demonstration onto the

growth test once the desired growth goal has been reached. There are a number of reliability growth models that can be used as described in MIL-HDBK-180. The Duane growth model is recommended since it is used most frequently and results follow the theory quite well. The AMSAA model is a second alternative and is very similar to the Duane model except that it permits the calculation of confidence intervals on the results. MIL-STD-1635 provides additional guidance for the planning of growth tests in the case of the Duane model.

3.0 MAINTAINABILITY

In order to achieve operational goals and minimize life cycle costs, the loader design must take into consideration maintainability factors. As with reliability, a number of maintainability problems exist with current loaders which should be corrected.

3.1 EXISTING 40K AND 25K LOADER MAINTAINABILITY PROBLEMS

Interviews with personnel operating and maintenance personnel have identified the following maintenance problems on current loaders:

- (a) Poor maintenance and operating manuals.
- (b) Elevating cylinders are very difficult to remove due to method of end pin removal
- (c) The delay times for some replacement parts is excessive.
- (d) Routine servicing cannot be performed without raising the deck.
- (e) If engine or hydraulic fail, there is no good way of raising or lowering the deck. Especially critical if failure occurs with deck loaded and deck is up.
- (f) Exhaust pipe access is poor when the loader is in the maintenance shop.
- (g) Oil bath fixtures are difficult to maintain.

3.2 MAINTAINABILITY DESIGN REQUIREMENT CONSIDERATIONS

Appropriate maintenance indices must be specified in order to assure that operational requirements and life cycles cost objectives are achieved, and that manpower constraints are not exceeded.

At the organizational level (on equipment maintenance), the mean time to repair (MTTR) must be specified since it has the most impact on system down time from an active maintenance point of view. The maximum corrective maintenance time at the 90th (or 95th) percentile should also be specified in order to assure that no repair actions require an excessive amount of time. If Built-In-Test/Built-In-Testing Equipment (BIT/BITE) is required, the percentage of faults to be detected, and the percentage of detected faults to be isolated to the correct line-replaceable item (LRU/component) should be specified.

The MTTR and maximum corrective maintenance time may be specified at the intermediate and depot levels of maintenance for repair of LRUs and components if required. The need for depot level specifications will depend on the amount of new design to be implemented and repaired at the depot and the intended maintenance concept.

Servicing, periodic and scheduled maintenance action requirements should be specified. The requirements may include a combination of maximum frequency and/or mean preventative maintenance time. Frequency requirements should differentiate between those actions which are based on calendar time and those which are based on operating hours.

If there are manpower constraints to be considered or as a control on life cycle costs, the maintenance manhours per operating hour must be specified. This parameter includes all types of maintenance and may be specified for each level of maintenance or as a combined parameter for all levels of maintenance. The method of specification will depend upon the objectives to be obtained.

In addition to numerical requirements, the maintainability specification should include those design and subjective requirements as necessary to insure that user objectives are achieved. These requirements might include operator servicing requirements, desired restrictions on scheduled and preventative maintenance, too.

3.3 MAINTAINABILITY DESIGN TECHNIQUES/CRITERIA

Design techniques which can be employed to improve the inherent maintainability of the loader are presented in the paragraphs below:

Operating and maintenance manuals must be detailed and clearly written.

BIT and BITE should be incorporated to facilitate on equipment maintenance where applicable.

Fluid level checks, refueling, battery maintenance, and other frequent preventative and scheduled maintenance actions should be accomplished without having to raise the deck or start the engine.

The design must provide for rapid, simple removal and replacement of line replaceable units at the organizational level of maintenance.

The loader must provide maximum access to LRU's in order to eliminate removals or facilitate maintenance.

A backup method for raising and lowering the deck should be provided in case of engine or hydraulic failure.

Organizational maintenance should be accomplished with a minimum number of standard tools. The need for ancillary test equipment should be eliminated or minimized.

Standard off-the-shelf parts and components with multiple suppliers should be used to the maximum extent possible.

Connectors should be uniquely keyed and individual connections color coded and/or numbered to prevent mis mating of interconnections during maintenance.

MIL-STD-1472C design criteria for weights, handles, accessibility, safety, etc. should be incorporated to the maximum extent possible.

The selection of filtering techniques for air and fluids must consider ease of servicing and maintenance.

3.4 MAINTAINABILITY PROGRAM

MIL-STD-471A provides a means to establish a comprehensive documented maintainability program plan.

The plan should contain the following tasks as a minimum:

- (a) Task 101 - Prepare maintainability program plan.
- (b) Task 102 - Monitor/control of subcontractors and suppliers.
- (c) Task 103 - Program and design reviews.
- (d) Task 104 - Data Collections, analysis and corrective action system.
- (e) Task 202 - Maintainability allocations.
- (e) Task 203 - Maintainability predictions.
- (f) Task 205 - Maintainability analysis.
- (g) Task 206 - Maintainability design criteria.
- (h) Task 207 - Inputs to detailed maintenance plan and LSA.
- (i) Task 301 - Maintainability demonstration.

3.5 MAINTAINABILITY TEST PROGRAM

In order to insure that maintainability objectives have been achieved, a maintainability demonstration must be conducted. MIL-STD-471A specifies several standard test procedures which may be used to accomplish the demonstration. Although the final selection of a test plan will depend upon the maintainability parameters specified, test method 9 of MIL-STD-471A is recommended for demonstration of mean repair time, mean preventative maintenance time, and maximum maintenance time. The test should include a means of evaluating operating and maintenance manuals and general design features. A checklist may be used for this purpose.

4.0 DEPENDABILITY AND AVAILABILITY

4.1 EXISTING LOADER AVAILABILITY PROBLEMS

Due to the low reliability of current loaders and the lack of timely spares, their surge availability is expected to be very low. In a research report written by Lt. Col May, the projected in commission rates of MHE after forty days of surge activity is only 50%. The same report noted shortages of MHE during the Vietnam conflict. The problems included ineffective depot level maintenance. These and related problems must be addressed during the development of a new loader. The section below will discuss the considerations that must be taken into account in determining an availability or dependability requirement for a new loader.

4.2 AVAILABILITY REQUIREMENT CONSIDERATIONS

The required dependability of the loader will drive the availability and resulting reliability and maintainability requirements. The relationships between these factors are complex and involve many other factors. A model for analyzing the various factors and their relationships will be developed in this section. For the purpose of the model, dependability, D, or readiness is defined as the probability that at least x out of n loaders are available for use during the specified period of time. It is related to the availability, A, by the relationship:

$$D = \sum_{i=x}^n \binom{n}{i} A^i (1-A)^{n-i}$$

The parameter, x, represents the minimum number of loaders at a given station required to perform a stated mission while the parameter, n, is the number of loaders assigned to the station. The minimum number of loaders required depends on:

- (1) The total tonnage or number of pallets to be moved over a given period of time;

- (2) The type(s) of aircraft to be serviced, their cargo limit in terms of both weight and pallets, the tonnage allocated to each aircraft type, and the maximum aircraft load time for each aircraft type;
- (3) The maximum weight limit, number of pallets, and turn around time of the loader;
- (4) The average pallet weight.

The determination of x requires a careful operations analysis for each base and/or the total fleet and may be an iterative process. The main objective is to determine the total loader hours required during the time period of interest, obtain the number of loaders required, and compare with the number of loaders required to meet the maximum aircraft load times. Consider the following example.

During a surge period 1000 tons must be handled daily. The base will service an aircraft capable of carrying 125,000 pounds and 36 pallets. The loader can carry 60,000 pounds and 6 pallets. The maximum aircraft load time is 4 hours and the loader turnaround time is 2 hours; one half hour each at dock and aircraft, and one half hour travel time one way. The average pallet weight is 4000 pounds. Since 1000 tons must be handled, 16 aircraft must be loaded. If each aircraft carries the maximum number of pallets (average weight 3470 pounds), the total number of pallets to be moved is 576 which will require 96 loader trips or 192 loader hours during the 24 hour period. The minimum number of loaders which will fulfill this requirement is 8. This result must be cross checked with the maximum aircraft load time. Since each loader trip requires one half hour to unload at the aircraft and six trips are required to complete aircraft loading, 3 hours are required to load an aircraft. The total aircraft load time per day is therefore 48 hours and 2 aircraft must be loaded simultaneously. An analysis of the scenario will show

that in order to load an aircraft in 4 hours, 4 loaders per aircraft are required. It may, therefore, be concluded that 8 loaders are sufficient (as a minimum). One only needs to change the scenario by assuming the average pallet weight and letting the number of pallets be the variable to obtain a completely different answer.

Once the minimum number of loaders has been obtained, the assigned number, n , can be determined by using the required value of D to solve for A and re-iterating until a reasonable value of A is obtained. Using the example above and a dependability requirement of 0.9, one gets the values shown in Table II for n and A . A value for $n = 8$ can be calculated but would not mean much since, in this example, the utilization time per day is 24 hours ($192/8$) which would leave no available down time an unrealistic assumption. An analysis of the operational availability must be performed to determine which of these value combinations to use.

The operational availability, A , is defined as;

$$A = (T_o + T_s)/(T_o + T_s + T_d) = (T_o + T_s)/T_c = T_a/T_c$$

where T_o = operating time,

T_s = standby time - the time that the loader is operational but unused,

T_d = down time due to active maintenance and delay time due to administration and parts unavailability.

T_c = calendar time

T_a = available time.

The minimum required operating time is determined from the operational analysis discussed above and is equal to the total loader hours divided by n . The other times are determined by simple arithmetic. Table II contains the derived values for the example described above based on a 24 hour calendar

time. The times for T_o represents the minimum times required for the operational scenario. T_o could be larger but will be limited by the resulting growth in down time as will be seen in the analysis of down time below.

Table II Example Availability Results

N	A	T_a	T_d	T_o	T_s
9	0.94	22.56	1.44	21.33	1.23
10	0.885	21.24	2.76	10.2	2.04
11	0.835	20.04	3.96	17.45	2.59
12	0.785	18.84	5.16	16	2.84

The down time has several components and may be represented by:

$$T_d = T_{da} + T_{ds} + T_{dd}$$

where T_{da} = down time due to active corrective maintenance,

T_{ds} = down time due to active scheduled, periodic, and servicing maintenance

and T_{dd} = down time due to delays and administrative time.

The down time due to active corrective maintenance, T_{da} , is;

$T_o \cdot \text{MTTR} / \text{MTBF}$ or the mean time to repair times the number of failures expected during the time T_o .

The second component of active maintenance down time is due to servicing and preventative/scheduled maintenance. It may be estimated from the following;

$$T_{ds} = T_o \cdot F_o \cdot T_{dso} + T_o \cdot F_c \cdot T_{dsc}$$

where T_{dso} = average service and pm maintenance time for those tasks based upon operating hours such as fluid level checks.

T_{dsc} = average service and pm maintenance time for those task based on calendar time such as a battery check once per month.

F_o = total frequency of service and preventative maintenance action based on operating hours.

and F_c = total frequency of service and preventative maintenance actions based on calendar hours.

The average maintenance times are calculated by the following;

$$T_{dso} = (\sum T_i * F_i) / (\sum F_i)$$

$$T_{dsc} = (\sum T_j * F_j) / (\sum F_j)$$

where T_i = time to perform i th service task performed after $1/F_i$ operating hours.

F_i = frequency of i th service task in expressed in terms of operating hours.

T_j = time to perform j th service task performed after $1/F_j$ calendar hours.

F_j = frequency of j th service task expressed in terms of calendar hours.

The down time due to parts unavailability is directly related to the number of expected failures, part ordering times, and the spares philosophy. Some delay times experienced by users of loader equipment in the SABER READINESS-INDIA report are shown in Table III. The delay time can also be expressed in terms of mean delay time;

$$T_{dd} = T_o * T_{ddm} / MTBF$$

where T_{dd} = down time due to delays and parts availability,

T_{ddm} = mean delay time per failure.

and $T_{ddm} = (\sum T_{ddi}(\lambda_i)) / (\sum \lambda_i),$

where T_{ddi} is the delay time for the i th component and λ_i is the failure rate of the i th component. T_{ddi} must take into account the probability of having available spares for the component under consideration. Suppose that the probability of having a spare available is P_i and that the delay time with spares is T_{dds} and without spares is T_{ddo} . Then the delay time for a component may be estimated as;

$$T_{ddi} = P_i * T_{dds} + (1 - P_i) * T_{ddo}$$

Table III Parts Lead Times for K-Loaders

ITEM	LEAD TIME (DAYS)
Main Hydraulic Pump	30
Main Drive Box	60
Control Cable Switch	10
Hydraulic Hoses & Fittings	20
Drive Wheels	18
Engine	60
Engine Starter	5
Carburetor	5
Alternator	5
Orbit Motor	60
Main Lift Cylinder	90

The operational availability now becomes;

$$A = (To+Ts)/[To(1+MTTR/MTBF+Tddm/MTBF+Fo*Tdso) + Ts +Tc*Fc*Tdsc]$$

The down time is:

$$Td = To(MTTR/MTBF+Tddm/MTBF+Fo*Tdso) + To*Fo*Tdso, \text{ or}$$

$$Td = [To(MTTR/MTBF+Tddm/MTBF+Fo*Tdso+Fc*Tdsc) + Tc*Fc*Tdsc]/(1-Fo*Tdso)$$

Of these terms, the delay time is potentially the greatest contributor to down time. Let $Td' = Td - Tds$.

$$\text{Then } Td'*MTBF/To = MTTR + Tddm$$

In the example above for $n = 12$, assume Td' is 4.16 hours and the MTBF is 100 hours. Then the $MTTR + Tddm$ is limited to 26 hours. Although this number seems high, the average delay can be very high. Using the approach to estimating $Tddi$ with spares rather loosely, assume that the overall probability of having a spare is 0.9, $Tdds$ is 4 hours, and the MTTR is 2 hours. Then $Tddo$ must be less than 204 hours or 8.5 days. Although the maintainability and reliability of the loader is extremely important, the achievement of any appreciable availability will require careful selection of parts for delivery

time and consideration of the logistics support functions. Spares requirements in particular will have to be carefully analyzed.

5.0 SYSTEM SAFETY

System safety must be considered in the design in order to eliminate or minimize the effects of known hazards in the current loaders and to insure that no new problems are introduced into new loader designs. The following paragraphs discuss some known safety problems, design criteria for new loaders, and a recommended system safety program.

5.1 EXISTING LOADER SAFETY PROBLEMS

Major safety problems with the current loaders are listed below. A new loader design should eliminate or minimize the effects of these problems. Base safety offices should be consulted to identify additional problems for corrective action not described here.

- (a) Driver visibility is limited. Causes accidents, injuries, and equipment damage.
- (b) Relative movement between the loader and aircraft caused by settling during operations can cause damage to the aircraft and/or the loader due to interference.
- (c) Relative movement due to settling and tilting of the loader also causes damage to aircraft and loader rails, dropped or damaged cargo, and cargo hangups. Very difficult to maintain alignment between aircraft and loader especially with long married pallets.
- (d) Pallet locks don't always engage or drop out during operations creating hazardous conditions to both personnel and cargo. Security of rolling stock is not reliable.
- (e) Ladder is not safe especially during adverse weather.
- (f) Personnel injuries (twisted ankles) from loader bed slots used for fork tines.
- (g) Back injuries from pushing cargo.
- (h) The present heater is unsafe to operate during concurrent aircraft fueling.

5.2 SYSTEM SAFETY DESIGN REQUIREMENTS

The loader design must incorporate safety and human factors design requirements to minimize operating hazards. General design requirements can be found in MIL-STD-1729, AFSC DH 1-6, MIL-STD-882B, and MIL-STD-454K, Requirement 1. In addition to general requirements, specific criteria should be generated based on experience and analysis.

5.3 SYSTEM SAFETY DESIGN TECHNIQUES/CRITERIA

System safety design criteria should be established for the loader in order to provide guidance to the designers and to provide an evaluation tool to assess the design. Techniques and criteria which should be included are listed below.

Electrical connection and terminals strips should have guards or barriers in accordance with MIL-STD-454K, Requirement 1.

Moving mechanical parts should have covers or barriers to protect operators or maintenance personnel from injury.

The system safety precedence of MIL-STD-882B, paragraph 4.4, should be followed.

Materials which release toxic fumes in case of fire should be eliminated to the maximum extent possible.

Ladders, walkways and safety rails should be designed in accordance with MIL-STD-1472C.

Provide caution and warning placards, decals, and notices on equipment as required by MIL-STD-1472C and MIL-STD-454K, Requirement 1.

Review and insure that adequate warnings and cautions are included in operating manuals and maintenance manuals.

Develop design techniques to eliminate existing hazards or control their effects.

5.4 SYSTEM SAFETY PROGRAM

A new loader development program should require the implementation of a documented system safety program plan in accordance with MIL-STD-882B. The task most strongly recommended are:

- (a) Task 101 - Prepare a system safety program plan
- (b) Task 102 - Monitor/control of subcontractors and suppliers
- (c) Task 103 - Program reviews
- (d) Task 105 - Hazard tracking and risk resolution

- (e) Task 106 - Test and evaluation safety
- (f) Task 202 - Preliminary hazard analysis
- (g) Task 205 - Operating and support hazard analysis
- (h) Task 207 - Safety verification
- (i) Task 209 - Safety assessment
- (j) Task 211 - ECPs, and request for deviation/waiver

In addition, Task 204 (system hazard analysis) is recommended in order to provide a more comprehensive analysis of hazards induced by failures. Either a fault tree or a fault hazard analysis is recommended. If a FMECA (see reliability section) is to be performed, a fault hazard analysis would be very economical to obtain.

**Appendix C HUMAN FACTORS
ENGINEERING STUDY AND EVALUATION
OR CURRENT AND FUTURE AIRCRAFT
LOADERS**

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1.0 INTRODUCTION

The purpose of this study is to evaluate the Human Factors engineering design of the current aircraft loader now in the Air Force inventory and present the results of this evaluation as recommendations for a future aircraft transporter-loader.

The recommendations are derived from evaluation methodology and sound human engineering judgment outlined and specified in the listed references. Each recommendation is documented by one of the specified references which will aid in the formulation of Human Engineering specifications for a new aircraft transporter-loader. The following study addresses the development of the workspace, control and display design, and training requirements as defined by the:

- Field Survey of Current Aircraft Loaders
- Definition of the Level of Complexity
- Definition of the Human Error Component
- Sample Task Analysis of Loader Aircraft Rendezvous and Mating

This evaluation and its subsequent recommendation attends to the following basic Human Engineering Parameters as a basis for measurement:

- Vision
- Perceptual Motor Capabilities - Recognition of a signal and mentally responding to that signal with a physical act, e.g., Loader Operator responds to Air Pressure Reading as an emergency condition and shuts the engine off.
- Cognition - Reasoning and interpreting processes involving one or more bits of information required to make a given decision. It involves the interplay between the short term and long term memory.
- Hearing
- Human Size and Physical strength.

All recommendations presented in this report involves each of these parameters where applicable.

term/long-term memory and thinking), and human size with a task complexity scale of 1 to 3. This conceptual approach is identified by:

<u>TASK COMPLEXITY LEVEL</u>	<u>APPROXIMATE SERVICE TIME</u>	<u>EXPECTED HUMAN PARAMETERS</u>	<u>EXTENT OF JOB KNOWLEDGE NEEDED TO DO TASK</u>
3-3.9	over 3 years (E-5)	perceptual motor, cognitive, and human strength	Thoroughly trained, extensive background, and experience
2-2.9	11 mo. to 3 yrs. (E-3, 4)	any two HFE parameters	Training completed but task knowledge and experience is not extensive or complete.
1-1.9	0 to 10 mo. (E-2)	1 HFE parameter	Still in training; familiar only with task procedure.

2.3 HUMAN ERROR DEFINITION (Reference a, Para. 4.1)

Human error refers to any member of a set of human actions that exceeds some limit of acceptability and is an out-of-tolerance action where the limits of acceptability are system-defined. It is a given that when any task is performed, an error will occur. It is also a given that some people have a greater probability for errors than others for a certain/specific set of tasks.

In order to arrive at a human error statement for a future aircraft loader, it is necessary to heuristically determine, from known tables, the Human Error Potential (HEP) and operator success for the current loader systems. Data and information obtained from the human error analysis will be used to develop hardware and training recommendations free of a high human error component.

The development of an estimated Human Error Potential (HEP) and Task Error Probability (TEP) for the current aircraft loader requires consideration of the following analytic steps:

- o Identify the characteristics of the current Loader Operator Personnel
 - The skills, experience, training, and motivation of the personnel who operate the current loaders are identified in Section

2.2 as E1, E2, E3, and E4 with E5 personnel being an exception. The capabilities and limitations of these operators must be understood so that their capabilities can be compared with a given level of system complexity. For example, if a system operated by a given population of users reflects a high human error component, this mismatch requires a change in the operator-machine interface and modification of personnel characteristics through training and/or selection.

- Sample and Describes the tasks that the operator perform.
 - A description of the current loader tasks is an integral part of the operator task analysis. The task description is an inventory of the specific behavior required of the operators to operate the equipment successfully. Table 1 is a sample of the basic tasks and the basic factors required to operate the current loaders.
- Analyze the tasks to identify Error-Likely Situations (ELS)
 - Each human action is analyzed to identify those independent error-likely situations arising from equipment design features, methods of use, level of training, and the skill level of the current operators. There are four factors to consider in identifying an error-likely situation. They, in the broadest sense, are:
 - Surveillance (perceptual) and scanning relative to anticipatory requirements
 - Recall requirements (long term/short term memory) and initiation of cue recognition
 - Interpreting requirements
 - Control manipulation and integration with other controls and displays
 - An error-likely situation arises when the discrimination recalling, interpreting, inferring, decision-making, and manipulating processes, demand of the operator are likely to exceed the operators's capacity.

Table 1 Human Factors Engineering Task Analysis and Evaluation
Current Cargo Loaders (25-40K) (Sheet 1 of 2)

1. Rendezvous and Vehicle Aircraft Mating/Cargo Removal Mode	2. Control/Location	3. Information Required to Carry Out Task	4. Operator Action/Activity	5. Operator Interaction	6. Information Available to Operator (Display, etc.)
a. Premaneuvering tasks					
(1) Start engine	Engine start switch on horizontal panel, right bottom edge under steering wheel Figure 1, Item 2B	Should not operate starter continuously for periods longer than 30 seconds. Limit the number of starting attempts to five or less before trouble shooting for no start.	Turn start. Run switch to "start" position and release to run. Depress throttle foot treadle to one-half open	N/A	a. Oil pressure meter, Item 3. b. Air pressure meter, Item 6. c. Duct current meter, Item 4.
(2) Move vehicle forward to 50' of aircraft and stop vehicle	Gear shift. Accelerator pedal full gauge. Brake pedal. Speedometer.	The overall length and width of the vehicle, in both the raised and lowered positions, requires that the vehicle have more space for maneuvering than a conventional vehicle of the same wheel base. An assured clear distance on each side of the vehicle should be determined before making a sharp turn in either direction. When operating in congested areas, the operator should seek the assistance of another individual to act as a guide in maneuvering the vehicle. This vehicle is equipped with a fully hydraulic power steering system. The steering is not self-centering. After turning, the operator must return the wheel to the straight ahead position. Must not reverse vehicle direction at high speed.	Releases brake; puts vehicle in appropriate gear for required forward speed and maneuvering. Uses turn signals and brakes vehicle to full stop. Sets brakes.	Interacts with a guide person posted on the ground.	Vehicle speed Oil, air, duct current
(3) Approach aircraft and stop 10' from aircraft port	Same as 2.	Same as (2).	Same as (2).	Same as (2).	Same as (2)

7. Feeds After Display	8. Feedback to Operator After Responding to Display	9. Task Complexity 1 to 3 See Table	10. Error Likely Situation Lik	11. Human Error Potential No = 0.00 Yes =	12. Task Error Probability (HEP x Task Complexity)	13. Critical Task Issue 1-Medium 2-High	14. Time Minutes	15. Required Skill Level	16. Remarks
Meter read position	Meter readings to normal position	2	Driver can drive vehicle while low pressure light is illuminated	.003	.006	2	10	1000	
			Driver can engage starter while flywheel is moving	.003	.006				
			Driver can engage starter while flywheel is moving	.003	.006				
Operator meter, et al	Operator reads speed meter, et al	3	Misinterpret verbal and visual signals of posted guide	.001	.003	2	15	1000	
			Misjudgment of maneuvering space	.001	.003				
			Maneuvering without ground assistance	.001	.003				
	Time as 2	1	Same as 2	.001	.001	2	5	1000	

Table 1 Human Factors Engineering Task Analysis and Evaluation
Current Cargo Loaders (25-40K) (Sheet 2 of 2)

1. Device and Vehicle Aircraft Mating/Conc. Removal Mode	2. Control Location	3. Information Required to Carry Out Task	4. Operator Action/Activity	5. Operator Interface	6. Information Available to Operator (Display, etc.)
4. Lowering Tasks					
1. Engage transmission lever in neutral position prior to power takeoff (PTO) engagement	Shift control (rotary valve, Figure 1, Item 1)	PTO is connected to the transmission and provides drive for main hydraulic pumps. To engage the PTO the transmission must be in the neutral position and air pressure buildup completed.	Initiate shift control to neutral position manually.	N/A	Air pressure indicator reads full pressure.
2. Engage PTO	PTO selector valve (Figure 1, Item 2)	The transmission is in neutral position and air pressure buildup completed.	Engage PTO lever (push).		Air pressure indicator reads full pressure.
3. Raise deck	Front/rear deck switch (Figure 1, Item 3)	The pallets must roll smoothly from the aircraft or deck floor to the loader deck. The loader deck must be properly positioned with respect to the airplane. A spotter must be positioned prior to alignment to aircraft and its deck floor. There are two slots in the rear of the deck to permit removal or placement of pallets by a forklift truck. Deck raising speed is varied by changing engine speed. Maximum engine speed is approximately 10 feet per minute.	With engine running, operator moves front/rear deck switch (14-15) to the up position and releases switch when the desired height is reached.	Operator attends to spotter and communicates via hand signals or portable radio.	Tachometer, no visual aid for height indication and loader deck position relative to the aircraft ramp door.
4. Lower the deck	Same as 3.	Deck lowering speed is at a fixed rate of approximately 10 rpm regardless of deck load or engine rpm. At 1500 rpm the deck will lower smoothly under any load condition.	Same as 3, except the front/rear deck switch is moved to the down position.	Same as 3.	Same as 3.
5. Deck pitch (lower front linkage)	Deck front switch (Figure 1, Item 4)	To lower only the front linkage, move the front lift control switch (17, Figure 1) to the down position, until the desired pitch is obtained.	Depress single switch down and hold until desired pitch is obtained, then let go. Switch returns to neutral automatically.	Information on pitch angle reported to operator by spotter.	Pitch gauge (Figure 14, Figure 1) provides visual level reference to the operator.
6. Deck pitch (raise front linkage)	Deck front switch (Figure 1, Item 4)	To raise only the front linkage, move the front lift control switch (17, Figure 1) to the up position, until the desired pitch is obtained.	Same except to hold in up position.	Same.	Same as 5.
7. Lower rear linkage	Deck rear switch (Figure 1, Item 5)	To lower only the rear linkage, move the rear lift control switch (18, Figure 1) to the down position. The automatic pendulum switch at the right front corner of the deck will stop deck downward travel in excess of 60° before any damage can occur to the aircraft.	Hold deck rear switch down and hold until desired height is obtained, then release switch. Switch returns to neutral in 15 sec.	Spotter interface.	Same as 5.
8. Raise rear linkage	Same as 7.	To raise only the rear linkage, move the rear lift control switch (18, Figure 1) to the up position.	Same as 7, except switch is held in up position.	Spotter interface.	Same as 5.
9. Roll deck left	Deck roll switch (Figure 1, Item 6)	This operation is needed when the deck must be aligned with a platform that slopes to the left, reference to driver.	Move roll switch to left.	Same as 18.	Roll gauge provides reference to other position (Figure 1, Item 6).

Feedback to Operator After Responding to Display	Task Complexity (1-5)	Error Critical Situation (1-5)	Major Error Potential (Yes/No)	Task Error Probability (0.001-0.1)	Critical Task (1-5)	Time (Minutes)	Reported Level (1-5)	Score
Gear lever in neutral position	2	Accidental engagement of transmission during air pressure build-up will cause the vehicle to lurch in direction of gear lever placement causing damage to the aircraft	Yes	0.01	1	1	111	
Operator feedback	3	Operator may toggle front rear deck switch incorrectly due to unorganized and operational sequencing and appropriate switch style and position labeling. Random up-down toggling action was observed in a demonstration by two experienced operators.	Yes	0.015	1	1	111	
Feedback is obtained from the spotter's confirmation of loader deck aircraft rendezvous.		Operator can misinterpret tachometer readings, be misled by confusing spotter communication, and a confusion with deck rear switch leading to its inappropriate initiation	Yes	0.05	1	1	111	
Same as (3)	3	Same as (3)		0.015 0.006 0.015	3			
Spotter info, visual reference to deck position and position of bubble in bubble level.	2	Confusion between similarity of switch function and position is responsible for selection of wrong control	Yes	0.01	2		111	
Same as (5)	2	Same as (5)	Yes	0.05	0.01		111	
Same as (6)	2	Same as (6)	Yes	0.01	2		111	
Same as (7)	2	Same as (7)	Yes	0.01	1		111	
Same as (8)	2	Same as (8)	Yes	0.01	1		111	

Task Error Probability (0.001-0.1)
Critical Task (1-5)
Time (Minutes)

- Estimate the likelihood of each potential error.
 - The importance of an error is a function of its frequency over time, probability of recovery, and potential consequences.
 - The human error studies (Reference (e) and (f) have estimated that an HEP range of 1.0 - .001 to 1.0 - .01 is both common and random. Those HEPs greater than .01 are considered to be critical. Table II was drawn from Reference (e). These data have been applied and used in other studies with predictive success.
 - When an estimate of an HEP for a task or a human action is made, the estimate is followed by a range, listed in parentheses, expressing the lower and upper HEP boundaries. The expression, .01 (.003 to .03) means that the best estimate of the HEP is .01 and that is unlikely that the HEP would be lower than .003 or higher than .03 (.997 or .97). That is, there is only 10% change that a HEP would be higher than .03 or lower than .003/ This means that the HEP of .003 represents the lower 5th percentile and .03 represents the upper 95th percentile. The following rule is used to establish the HEP boundaries.

HEP	LOWER	UPPER
HEP .001	HEP/10	HEP X 10
HEP .001 TO .01	HEP/3	HEP X 3
HEP .01	HEP/5	HEP X 2 to 5

2.4 THE DEFINITION OF OPERATOR TASKS AND THEIR RELEVANCE TO THE DEVELOPMENT OF SPECIFICATIONS FOR A FUTURE AIRCRAFT LOADER (Reference C, Para. 3.2.1.3)

The development of a task inventory and its analysis identifies how the current loader is operated and what is needed for successful operation of future loader. Identification of specific recommendations to Human Engineering design of the future loader can be abstracted from a preliminary task analysis prior to first design review. Emerson HFE conducted such an analysis of the current 40K loader now in the Air Force inventory to determine and document recommendations pertinent to control/display design and the reduction of current aircraft damage history.

Table II Estimate of Human Error Potential (Sheet 1 of 2)

TASK	HEP
1. Walk-around inspections; recognize incorrect status, using checklist correctly	.01 (.005 to .05)
2. Walk-around inspections; recognize incorrect status, using checklist incorrectly	.1 (.05 to .5)
3. Walk-around inspections; recognize incorrect status, no checklist, first walk-around	.9 (.5 to .99)
4. Use checklist correctly	.5 (.1 to .9)
5. Follow established policies or procedures	.01 (.003 to .03)
6. Passive inspection	.1 (.05 to .5)
7. Respond to an annunciator (one of one)	.0001 (.00006 to .001)
8. Read annunciated lamp	.001 (.0005 to .005)
9. Read digital display	.001 (.0005 to .005)
10. Read analog meter	.003 (.001 to .01)
11. Read analog chart recorder	.006 (.002 to .02)
12. Read graph	.01 (.005 to .05)
13. Read printing recorder (cluttered)	.05 (.01 to .2)
14. Record more than 3 digits	.001 (.0005 to .005)
15. Detect a deviant meter with limit marks during initial audit	.05 (.01 to .1)
16. Check-read specific meters with limit marks	.001 (.0005 to .005)
17. Check-read specific meters without limit marks	.003 (.001 to .01)
18. Check wrong indicator lamp in a group of similar lamps	.003 (.001 to .01)
19. Note incorrect status of an indicator lamp (in a group)	.99 (.96 to .998)

Table II Estimate of Human Error Potential (Sheet 2 of 2)

TASK	HEP
20. Note incorrect status of a legend lamp (in a group)	.98 (.96 to .996)
21. Remember oral instructions, one of one	.001 (.0005 to .005)
22. Select wrong panel control:	
a. Among a group of similar controls	.003 (.001 to .01)
b. If functionally grouped	.001 (.0005 to .005)
c. If part of a minic-type panel	.0005 (.0001 to .001)
23. Set a multiposition switch	.001 (.0001 to .01)
24. Mate a connector	.01 (.005 to .05)
25. Turn control in wrong direction:	
a. If no violation of population stereotype	.0005 (.0001 to .001)
b. If population stereotype is violated	.05 (.01 to .1)

The field survey identified some areas of design concern that needed further detailed analysis and evaluation of a current loader to support and document specified recommendations for a new design. A task analysis sampling of the rendezvous and Vehicle-Aircraft Mating (Cargo Removal Mode) by function and task was conducted. An explanation of the Human Factors measures used and results of the task analysis is contained as follows:

- Control/Location

The layout of the control panel on the 40K and 25K loaders is composed of a scattering of switching dials and rotary controls that are not properly located, grouped, or labelled. These controls are marked with an * on Figure 1 for each task in Table I in order to demonstrate their scattering and the steering wheel interference. The Emerson Human Engineer with a 7th percentile arm reach could not reach the controls under and around the steering wheel. The current control panel design does not comply with Reference a.

- Information Required to Carryout Task

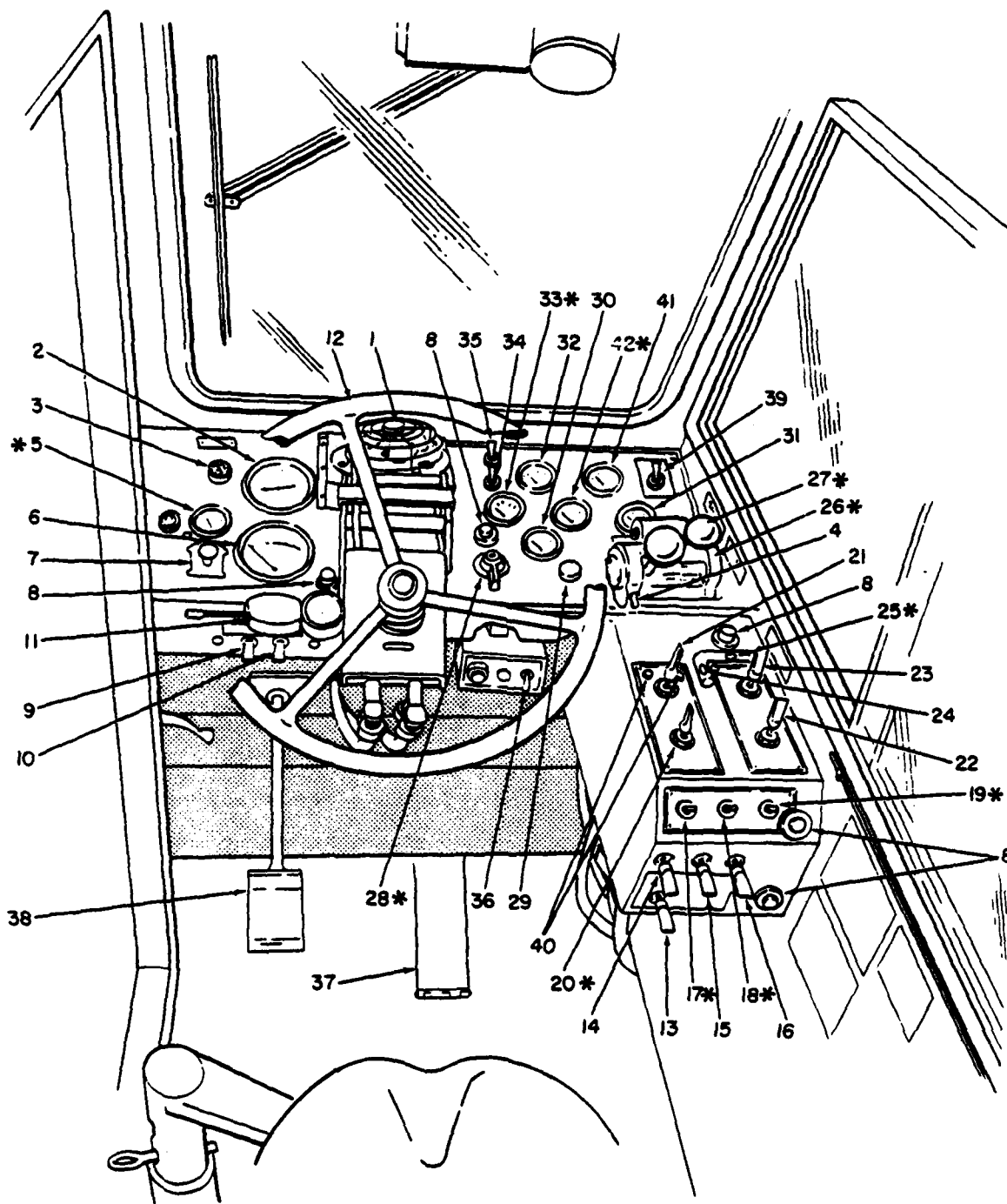
Analysis of this factor finds a dense field of data and information that has to be remembered from an intense on-the-job based instructional period. The category IIIB person cannot with any measure of success retain this important information from a simplistic on-the-job training process. The information required imposes a heavy cognitive load upon the difficult to maintain, short-term/long-term memory connection. This factor as an table of organization referenced OJT concept leads to a human error component usually isolated by a formalized training period.

- Operator Action/Activity

The activity of the operator with current cargo loader is, as expected for this factor, central to the operation and maneuvering of the loader. The operator action is driven by the heavily loaded "information required to carry out the task".

- Operator Interactions

The only interaction the operator has is with a "spotter" who assists the loader operator and his rendezvous with the aircraft. This factor is a source of error.



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Figure 1 Purpose and Use of Cab Operating Controls and Instruments
(Sheet 1 of 3)

INDEX	NOMENCLATURE	PURPOSE OR USE
1	Defroster Fan	Defrosts windshield.
2	Speedometer-Odometer	Indicates vehicle speed to 30 mph; indicates miles traveled.
3	Low Air Pressure Warning Light	Lights if air pressure falls below 60 psi.
4	Reverse Stop Lever	Used to release selector lever.
5	Air Pressure Gauge	Indicates air pressure in psi.
6	Tachometer	Indicates engine rpm's.
7	Parking Brake Knob	Pull to set parking brake, push to release parking brake.
8	Dash Light	Illuminates instrument panel.
9	Headlight Switch	Turns headlights ON and OFF.
10	Clearance Lights Switch	Turns clearance lights ON and OFF.
11	Turn Indicator Switch	Actuates left and right turn indicator lights.
12	Steering Wheel	Hydraulic power steering.
13	Dash Light Switch	Turns dash light ON and OFF.
14	Deck Lights Switch	Turns deck flood lights ON and OFF.
15	Chassis Lights Switch	Turns chassis flood lights ON and OFF.
16	Cab Lights Switch	Turns cab flood lights ON and OFF.
17	Deck Front Switch	Front deck up and down positioning.
18	Deck Front-Rear Switch	Front-Rear deck up and down positioning.
19	Deck Rear Switch	Rear deck up and down positioning.
20	Deck Roll Switch	Deck rolls to right or left.
21	Deck Side Shift Switch	Deck side shifts to right or left.
22	Mobility Switch	Retracts mobility rests.
23	Winch Switch	Provides power for winch reel out or winch reel in.
24	Pitch Bubble Level	Provides visual deck pitch reference to the operator.
25	Roll Bubble Level	Provides visual deck roll reference to the operator.
26	Shift Control (Rotary Valve)	Provides forward, neutral, and reverse shifting.
27	PTO Selector Valve	Engages and disengages the power takeoff.
28	Engine Start Switch	Engine starting. Turn, start and run switch to start position until engine starts.

Figure 1 Purpose and Use of Cab Operating Controls and Instruments
(Sheet 2 of 3)

NDEX	NOMENCLATURE	PURPOSE OR USE
29	Horn Button	Actuates horn.
30	Fuel Gauge	Indicates engine fuel level.
31	Hourmeter	Indicates operating hours of engine.
32	Water Temperature Gauge	Indicates engine water temperature.
33	Oil Pressure Gauge	Indicates engine oil pressure psi.
34	Defrost Fan Switch	Controls defroster fan motor.
35	Windshield Wiper Switch	Controls electric windshield wiper motor.
36	Heater Control	Controls cab heater.
37	Accelerator Pedal	Controls engine speed.
38	Brake Pedal	Controls air service brakes.
39	Emergency Shutoff Switch	Used for emergency shutdown, such as throttle or governor failure or other events.
40	Deck Shift Lights	Indicates deck shifted right or left of center.
41	Oil Temperature Gauge	Indicates transmission oil temperature.
42	Ammeter	Indicates charging rate of engine alternator.

Figure 1 Purpose and Use of Cab Operating Controls and Instruments

(Sheet 3 of 3)

- Information Available to Operator
The information available to the operator regarding the operational status pertains only to pressure gauges, speedometer, tachometer, and bubble levels. There is no visual aid or display available to the operator. The Loader Deck position has no indicated or displayed information except for that given to him by the spotter.
- Feedback to Operator after Responding to Display
Feedback refers to the knowledge of results that a person receives about the status or adequacy of his outputs. Without the feedback loop, the operator operates as an open loop system and cannot perform complicated activities reliably. Feedback is time restricted, a few seconds between the operator's action and the recognition that the act has been completed can degrade performance for continuous tasks. There is not timely feedback to the operator after he has, for example, raised the deck to the appropriate level other than a signal from the ground based spotter and/or his visual cue of the deck position which often has to be verified by the spotter.
- Task Complexity (See Section 2.2)
The mean task complexity score of 2.25 indicates that current loaders should employ operators who can handle simultaneous cognitive and perceptual motor activities and have completed a training course on cargo loaders. The emphasis is on formal training and knowledge rather than the current OJT approach.
- Error Likely Situations (ELS)
These factors were abstracted from Reference (d) description of the Loader aircraft rendezvous. There are 34 ELSs for nine tasks, approximately four error likely situations per task.
- Human Error Potential (See Table II)
The scores listed were obtained from parallel task/control estimates associated with control dynamics stipulated in Reference e. Each task has a potential human error component. It is not a probability score.

- Task Error Probability (TEP)

This task score, a product of the HEP and task complexity is an optimum score of a computed range as stated in Section 2.3 of this report. The nine sampled tasks have an estimated Task Error Probability score of 0.24 and a Human Reliability of 0.76. An error figure of 24% is extremely high and must not be inherited by the future loader design. This is a consequence of not following good human engineering design defined by Reference a, paragraph 4.1 and 4.4. The major portion (88%) of the human error component was derived from the task sample associated with the maneuvering switch configuration.

- Critical Tasks

There are, in the total inventory of tasks, for any man/machine system those tasks that:

- If not performed correctly, would impair and degrade the success of the mission.
- If ignored or not performed correctly, would be a hazard to personnel and equipment.
- May have a minimum hold time between the need for its performance and the actual time the task must be initiated and performed.

Emerson HFE has identified these factors in the task analysis and ranked them according to their critical impact on the system and the mission i.e., Low, Medium, and High. The current sample of tasks were judged by the above three criteria and their impact as detailed in Reference (d). The sample task analysis revealed the critical task structure to be moderately high (score = 2.36).

3.0 RECOMMENDATIONS

The foregoing analysis and evaluation of the current aircraft loaders provide a rationale and strong documentation for the following design recommendations to be included in the development of specifications for an advanced state-of-the-art aircraft loader.

3.1 WORKSPACE RECOMMENDATIONS (Reference a, para. 5.12.2, pp. 215-220)

- The Key Geometric and Dimensional features of the cab design have been specified by Reference (a) to accommodate 90% of Air Force male and female population. This definition illustrated in Figure 2 details the following recommended cab clearances and measures:
 - A. Elbow (Dynamic) 36 in.
 - B. Elbow (Static) 28 in.
 - C. Shoulder 23 in.
 - D. Knee Width (Minimum) 18 in.
 - E. Knee Width (Optimum) 24 in.
 - F. Boot-Provide adequate clearance to operate brake pedal without inadvertent acceleration operation 6 in.
 - G. Pedals (Minimum) 2 in.
 - H. Boot-Provide adequate clearance to operate accelerator without interference by brake pedal 6 in.
 - 1. Head (SRP to roof line) 42 in.
 - 2. Abdominal (Seat back to steering wheel) 16 in.
 - 3. Front of knee (Seat back to manuals/controls on dash) 29 in.
 - 4. Seat Depth (Seat reference point to front edge of seat pan) 16 in.
 - 5. Thigh-Underside of steering wheel to seat pan 9.5 in.
 - 6. Seat Pan Height 15 in.
 - 7. Boot (Front of seat pan to heel point of accelerator) 14 in.
 - 8. Mitten clearance around steering wheel 3 in. (Min)
 - 9. Knee-Leg-Thigh (Brake-Clutch Pedal) to lower edge of steering wheel 26 in.

There is a direct association between these dimensions and operator performance. If any one of these measures is compromised, the operator's performance will be degraded, resulting in an increased probability of human error leading to personal injury and/or aircraft damage. None of the current cargo

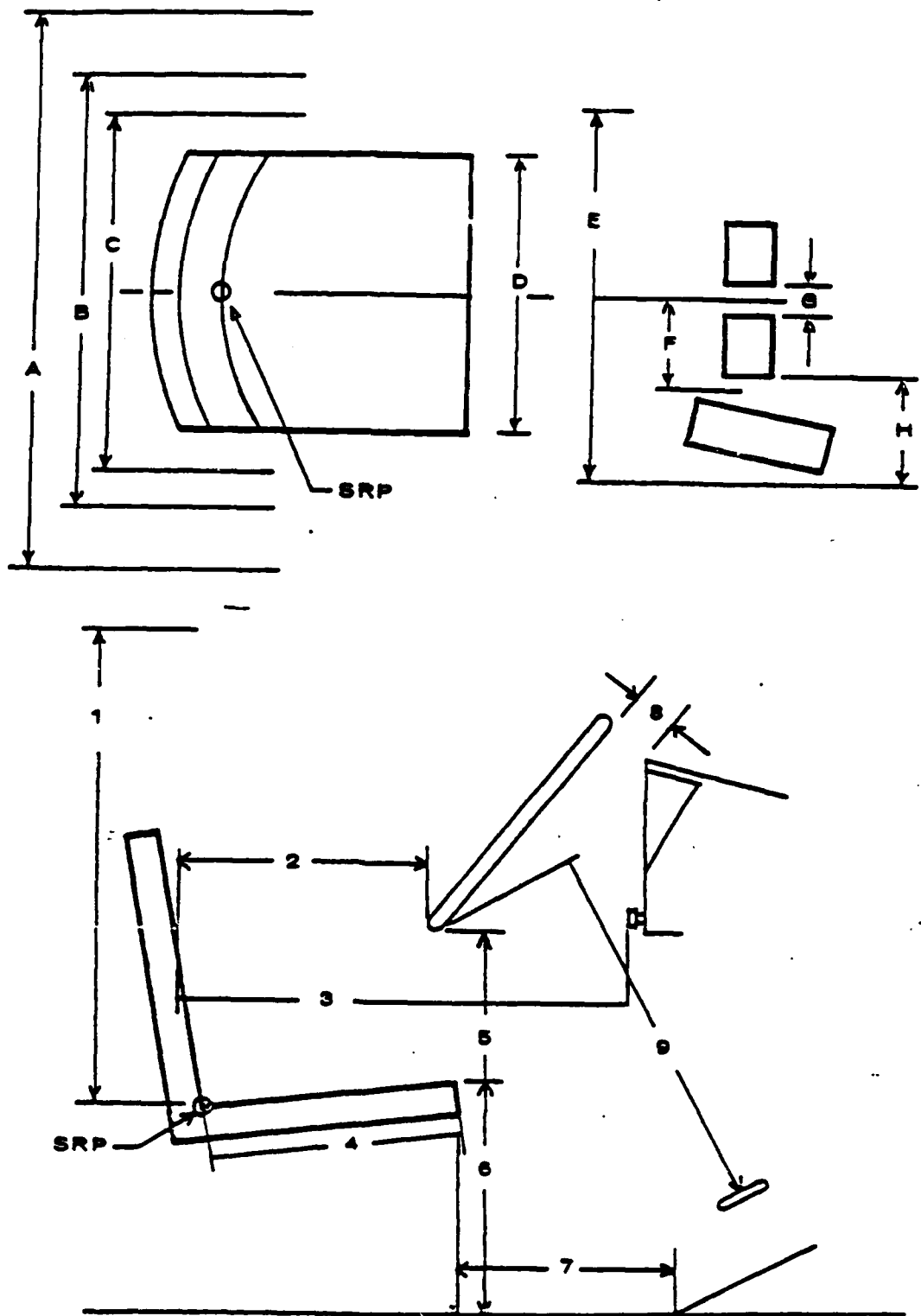


Figure 2 Recommended Clearances Around Equipment Operator's Station

loaders in the Air Force inventory reflect the required anthropometric measures (Section 4.1). This omission is associated with an excessive aircraft damage record.

The cab geometry is a major variable that is linked to the nature and quality of control panel design and training. This approach will be developed on the discussion of the preliminary task analysis relative to the maneuvering procedure.

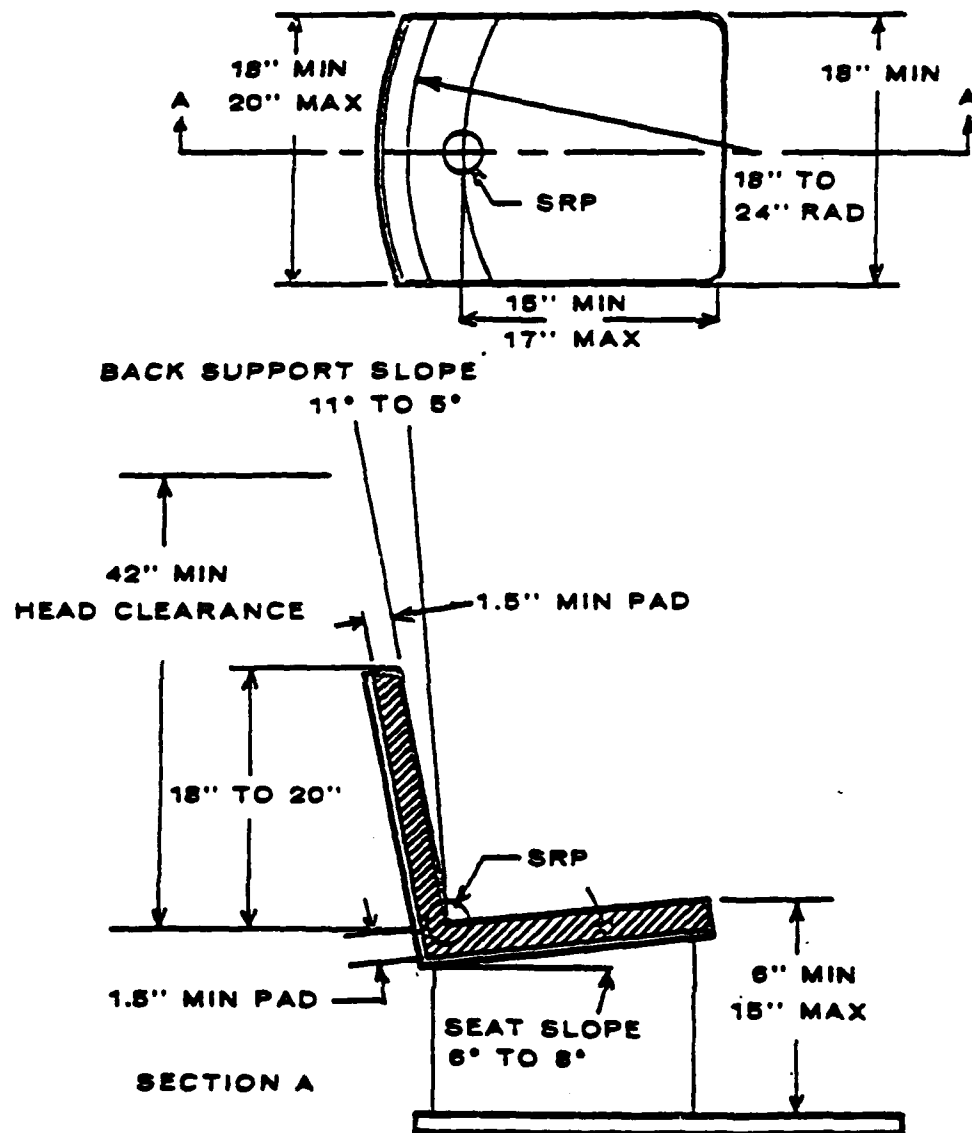
Seating design is an imperative that requires considerable attention for reducing fatigue during stressful loading durations of 24 hours or more. Reduction of fatigue will enable the operator to use the controls and displays more efficiently with minimal operational error and subsequent aircraft damage. Figure 3 reflects the recommended dimensions defined in Reference a, paragraph 2.2.2, pp. 215).

One additional requirement that is also an imperative is the vertical and horizontal adjustment of the seat allowing the operator to select the optimum interface geometry for him/her.

3.2 RECOMMENDATIONS FOR CONTROLS AND DISPLAYS (Reference a, para. 5.1)

Emerson HFE has analyzed and evaluated the control/displays common to the 40K loader and their effect on the quality of the loader performance. The current control/display configuration need improvement and redesign. To ensure improvement, the control/display design of a new loader should considered the following:

- The function of the control relative to its purpose and importance to the lifting and mating tasks.
- The requirement of the lifting task - primarily the precision, speed, range, and direction of deck movement.
- The trade-off or effect of reducing one set of task requirements to improve human reliability, e.g., reducing the six separate deck positioning switches to one analogy X-Y hand controller with an analog flat panel display (details to follow).



SRP-Seat reference point is point where seat back and seat cushion intersect.

Figure 3 Dimensions for Vehicle Operator's Seat

- The informational needs of the operator, i.e., meeting the operator requirements for locating and identifying the control, determining the control position (setting), and sensing the control position and sensing any change in control position for each of the delicate rendezvous and mating tasks.
- The requirements imposed upon the cab work space relative to the amount of and location of available space for control placement, the importance of locating a control/display in a specific position for proper grouping and/or association with other equipment, controls and displays which would ensure against accidental activation - i.e., grouping Vehicle-in-Transit controls separate from Engine Status.
- Visibility of all displays from the normal working position.
- Compatibility of display association with the functions they display and the special problems of displays not being in the same spatial plan with the controls and equipment with which it must be compatible.
- Combination of several position markers into a single integrated display (analog flat panel display for rendezvous and mating the loader with the aircraft).

The sample task analysis and detailed examination of the control inventory for the 25 and 40K loaders indicate no human engineering effort to prioritize, group and associate controls with displays relative to the delicate loading requirements. Specific control layout recommendations follow.

3.2.1 Control Priority

- Place initial function controls within 15° of operators normal line-of-sight. Such controls and displays are warning lights and associated switches.
- Place primary controls and displays in areas which optimize work flow.
- Place emergency controls and displays in readily accessible positions.
- Place secondary controls within areas determined by proper grouping and association. The data from task analysis will be utilized for this rule.
- Place low priority, infrequently used and low criticality controls where feasible.

3.2.2 Control Grouping

The grouping of controls and displays will follow two applicable methods:

- The functional grouping of all controls and displays that are identical in function and/or to be used together in a specific task or are related to one component (e.g., all controls and displays pertaining to a given sensor).
- The sequential grouping of all controls and displays that are operated or observed in sequence are grouped together and are arranged in their normal order of use.

3.2.3 Sequential Grouping

The sequential grouping of controls is critical and the "normal order of use" will be refined by task analysis which will reflect the following:

- Sequential grouping of controls and displays for check reading.
- The sequential grouping and alignment of controls horizontally, left to right, vertically, top to bottom, and in rows from top to bottom and from left to right within a row.
- The arrangement of controls and displays within the visual and manual area of the operator.
- The arrangement of a large number of displays that must be viewed in sequence in row rather than in columns.

4.0 OPERATOR CAPABILITIES, EQUIPMENT INTERFACE, AND THE TASK CRITICALITY RELATIVE TO TRAINING

The analysis of the sample tasks considered pertinent control and performance variables required to complete each task with an associated Task Error Probability. These performance variables identify a learned stimulus response configuration that requires a formal training program of the airman with the following characteristics:

- GT score of 87 to 110
- Six months to three years experience
- Education beyond the ninth grade

Further inspection of the task analysis identifies those items within the operational sequence that require explicit training emphasis and those that do not. For example, the operator must know that he/she must engage the transmission lever and then the PTO prior to raising the deck and maneuvering towards the aircraft. The operator, in order to complete this task without error, must have an understanding of the shifting tasks relative to transmission engagement and the kind of decisions that are necessary to prevent and/or correct potential hazard without endangering the aircraft. Such events as these need more precise and specific attention in a formal training program rather than the very informal and general training acquired by OJT.

The sample tasks analysis indicates that training could be divided into three developmental stages where:

- Performance is under conscious control. This means that the trainee must initiate conscious thought for each task initiation and completion.
- Performance is under shared control, i.e., some tasks require conscious effort and some do not, that is, their initiation and completion are automatic.
- Performance is totally automatic with near zero human error. This means that all the responses have been learned and set to long-term memory. It also permits the airman to improve his performance as he gains experience.

The total time for skill development marked by the three learning stages of ten days each for a total training period of 30 days which is consistent with the capability of the airman defined in this report.

5.0 HARDWARE RECOMMENDATIONS

5.1 CONTROL AND DISPLAY

There are 42 separate controls, 16 of which are switches, 14 are of the older toggle type switch, 9 are the older glass face gauge/dial type, 2 bubble

levels, some deck shift lights, and 3 shift type controls. The panel space and area can be reduced approximately 30% by replacing:

- The older toggle switches with flush mounted lighted push button switches.
- The older open glass faced gauge meters with digital readouts.
- Bubble levels with an analog display on flat electroluminescent display panel (See Section 5.2).
- Deck shift lights with LEDs.

5.2 REPLACEMENT OF PITCH, ROLL, AND SLIDE SWITCHES

The pitch, roll, and slide switches can be replaced with a hand control level (X-Y movement) with a stop-go trigger switch mounted in the handle (available on-the-shelf). This control can be linked between sonic transducers mounted on the rear and front ends of the deck and an electroluminescence (EL) flat panel ("5 X 7") which would display position/distance related (x, y, z axis) analog bar signals. Front, rear, pitch, up and down, roll left-right, and slide left-right visual display capability would reduce error and make rendezvous and aircraft mating a faster operation.

The hardware is an on-the-shelf equipment item manufactured by Polaroid. The sonic sensors are devices that respond to object proximity translated by a voltage signal. EL flat panels can be obtained from numerous sources.

The current visual and physical stress and associated operator-spotter configuration results in aircraft damage and a longer rendezvous and docking (mating) period.

6.0 ENVIRONMENTAL REQUIREMENTS AND RECOMMENDATIONS RELATIVE TO THE WORKSTATION CONTROL/DISPLAY AND HARDWARE DESIGN

Aircraft loading operations may be required in arctic regions or in areas of Nuclear, Biological, or Chemical (NBC) warfare; therefore, the cab, controls, and displays must accommodate the operator wearing the maximum arctic or NBC equipment as described in Air Force Regulations.

The workspace recommendations contained in Section 3.1 provide for 90% of Air Force male and female population wearing NBC and arctic clothing.

Appendix D LIST OF PARTICIPANTS

LIST OF PARTICIPANTS

<u>NAME</u>	<u>OFFICE SYMBOL</u>	<u>LOCATION</u>
Mr. L. Abila	HQ MAC/LGTX	Scott AFB, IL
Mr. E. Allen		Lockheed-Georgia Aircraft Co, Marietta,GA
Mr. M. L. Allen	WR-ALC/MMTV	Robins AFB, GA
MAJ J. Albany	HQ MAC/LGTV	Scott AFB, IL
CMSgt A. Anderson	HQ MAC/TRA	Scott AFB, IL
SMSgt D. Armantrout	HQ MAC/LGSW	Scott AFB, IL
Mr. R. Auer	AFCSA/STRNC-UAS	Natick R&D Center, MA
Mr. H. Ball		Boeing Aircraft Co., Seattle, WA
CPT K. Bass	HQ MAC/TRXF	Scott AFB, IL
CPT H. Batchelor	605/MASS/TROC	Anderson AFB, Guam
Mr. D. Bell	WR-ALC/MMTRA	Robins AFB, GA
Mr. D. Blum		Lockheed-Georgia Aircraft Co, Marietta,GA
MSgt J. Bosak	436TRANSP/LGTM	Dover AFB, DE
MAJ S. Boynton	HQ MAC/TRXF	Scott AFB, IL
MSgt Brock	2 MAPS/TRM	Little Rock AFB, AR
LTC E. Buchanan	HQ USAF/LETC	Pentagon, WDC
Mr. B. Byers	ASD/AEGA	Wright-Patterson AFB, OH
MAJ R. Byrd	HQ MAC/XPACRA	Scott AFB, IL
Mr. T. Cabral	HQ AFLC/LOC/CFSW	Wright-Patterson AFB, OH
Mr. B. Cannon		Douglas Aircraft Co., Long Beach, CA
Mr. J. Carbullido	HQ AFLC/MMII	Wright-Patterson AFB, OH
MSgt R. Chappius	HQ MAC/TRKO	Scott AFB, IL
SSgt S. Chatfield	374APS/TROC	Clark AFB, Phillipines
Mr. J. Cho		Korean Airlines, LAX, CA
Mr. F. Coker	HQ MAC/TRXF	Scott AFB, IL
SSgt S. Connelly	436/APS	Dover AFB, DE
Sgt K. Cook	DSTA	Kelly AFB, TX
Mr. G. Cooper	HQ AFLC/LOC/TLWS	Wright-Patterson AFB, OH
MAJ R. Cox	HQ MAC/TRKO	Scott AFB, IL
CPT M. Crinfield	HQ MAC/TRXM	Scott AFB, IL
CMSgt Cumberland	2 MAPS/TRM	Little Rock AFB, AR
COL M. Daniel	HQ 22AF/TR	Travis AFB, CA
TSgt D. Dassenbrock	619/MASS	Hickam AFB, Hawaii
TSgt J. Davis	HQ MAC	Scott AFB, IL
SMSgt W. Decker	HQ 22AF/TRXF	Travis AFB, CA
MAJ H. Edie	HQ MAC/XPSS	Scott AFB, IL
Mr. A. Edwards	HQ AFLC/DSTMV	Wright-Patterson AFB, OH
MAJ R. Ege	ESD/OCMS	Hanscom AFB, MA
MAJ J. Evans	HQ/USAF/RDQL	Pentagon, WDC
Mr. W. Evans	WR-ALC/DSTA	Robins AFB, GA
COL C. Eugenides	HQ MAC/TR	Scott AFB, IL
Mr. H. Farris	DSTOM	Kelly AFB, TX
CMSgt Fields	2 MAPS/TRMC	Little Rock AFB, AR
Mr. V. Flieller	DST	Kelly AFB, TX
LT R. Friedlander	ESD/OCMS	Hanscom AFB, MA
Mr. M. Fronkier	HQ AFLC LOC/CFSW	Wright-Patterson AFB, OH

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Mr. J. Gibson		Lockheed-Georgia Aircraft Co, Marietta,GA
Mr. K. Glasser	HQ USAF/LEYS(EDS)	Pentagon, WDC
COL J. Grant		Dover AFB, DE
MAJ J. Gronhard	HQ MAC/XOSX	Scott AFB, IL
MAJ D. Grube	HQ MAC/XOXA	Scott AFB, IL
Mr. R. Grueber		Douglas Aircraft Co., Long Beach, CA
Mr. M. Harn	NRDC/STRNG-UAS	Natick R&D Center, MA
MAJ J. Harpole	ATSP-CD-CS	Ft. Eustis, VA
CMSgt R. Hassinger	HQ 22AF/TRE	Travis AFB, CA
Mr. G. Haynes	DSME	Kelly AFB, TX
CMSgt B. Hewlett	436 APS/TRO	Dover AFB, DE
Mr. B. Hill	DSTAB	Kelly AFB, TX
CPT Hodge	611/MASS/TROC	Osan AB, Korea
Mr. J. Hodge	ASD/ENEGF	Wright-Patterson AFB, OH
Mr. George Holland		Boeing Aircraft Co., Seattle, WA
Mr. R. Holmes	WR-ALC/MMTRA	Robins AFB, GA
MSgt E. Huckaby	HQ MAC/XOSX	Scott AFB, IL
W. C. Hunt		Lockheed-Georgia Aircraft Co, Marietta,GA
TSgt G. James	22AF/TRXF MAC	Travis AFB, CA
MSgt R. Jecker	HQ TAC/LGTA	Langley AFB, VA
Mr. J. Jobson		Georgia Lockheed
LT G. Johnson	WR-ALC/MMTV/SAC-OL	Robins AFB, GA
LTC G. Johnson	HQ MAC/TRXF	Scott AFB, IL
MAJ C. Jordon	436APS/TROO	Dover AFB, DE
Mr. C. Kline		Douglas Aircraft Co., Long Beach, CA
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Mr. A. Kuecker	TWA-St. Louis	Lambert Int'l Airport, St. Louis, MO
Mr. D. Langstraat	Consultant	Lockheed-Georgia Aircraft Co., Marietta,GA
Mr. R. Latham	HQ AFLC/LOC/CFSW	Wright-Patterson AFB, OH
Mr. E. Lewis, Jr.	436 APS	Dover AFB, DE
BRIG GEN C. H. Lindsey	HQ USAF/LET	Pentagon, Washington, D.C.
CMSgt J. Lis	HQ MAC/XPQA/XPQC	Scott AFB, IL
TSgt T. Lund	21AF/TRXF	McGuire AFB, NJ
Mr. H. Macey	NFEC	NFEC, VA
Mr. E. Maldonado	DSME	Kelly AFB, TX
CW3(P) B. Manning	HQ MAC/LNA	Scott AFB, IL
MAJ M. Martello	2 MAPS/TRMV	Little Rock AFB, AR
LTC M. Mayes	HQ MAC/TRXF	Scott AFB, IL
SMSgt A. McFarlan	HQ MAC/TRKO	Scott AFB, IL
Mr. D. McGhee	436 APS/TRO	Dover AFB, DE
CPT A. McKinney	2 MAPS/TRMV	Little Rock AFB, AR
SRA G. McLean	314 TRANS/LGTM	Little Rock AFB, AR
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COL R. Meyer	HQ MAC/TRX	Scott AFB, IL
COL W. Miller	HQ MAC/LG-R	Scott AFB, IL

<u>NAME</u>	<u>OFFICE SYMBOL</u>	<u>LOCATION</u>
Mr. L. Milligan		Lambert Int'l Airport, St. Louis, MO
Mr. B. Minnich		Douglas Aircraft Co., Long Beach, CA
LTC T. Monheim	HQ USAF/LEYW	Pentagon, WDC
Mr. L. Morgan	00-ALC/DSTA	Tinker AFB, OK
Mr. B. Morrison		Douglas Aircraft Co., Long Beach, CA
MAJ G. Moses	HQ MAC/XPSR	Scott AFB, IL
TSgt S. Mosier	DSTAB	Kelly AFB, TX
Mr. G. Nash		Boeing Aircraft Co., Seattle, WA
Mr. J. Nelson		JFK Airport, NY
Mr. P. O'Brien	ASD/ENCA	Wright-Patterson AFB, OH
Mr. C. Outran	HQ AFLC/DSTMA	Wright-Patterson AFB, OH
Mr. R. Owen	WR-ALC/MMTRBV	Robins AFB, GA
MSgt M. Parker	603/MASS/TROC	Kadena, Japan
MAJ Passchier	HQ MAC/TRXP	Scott AFB, IL
CPT S. Perkins	HQ MAC/LGTX	Scott AFB, IL
LTC R. Plasse	2750 LS/DMT	Wright-Patterson AFB, OH
LTC J. Poe	HQ MAC/XPSS	Scott AFB, IL
MAJ J. Prather	HQ MAC/TRXM	Scott AFB, IL
MSgt D. Pratt	436 APS	Dover AFB, DE
Mr. E. Pratt	WR-ALC/MMSREA	Robins AFB, GA
CPT E. Pressley	LOC/XQLC	Wright-Patterson AFB, OH
TSgt R. Radford	2 MAPS/TRMV	Little Rock AFB, AR
Mr. L. Radlof	HQ AFLC/LOC/CEWA	Wright-Patterson AFB, OH
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COL R. Reedick	DST	Kelly AFB, TX
Mr. R. Reid	USA ABNSOT Board	Ft. Bragg, NC
Mr. R. Roberts		Boeing Aircraft Co., Seattle, WA
Mr. E. Rodriguez	DSMPB	Kelly AFB, TX
Mr. M. Rohrlick		Lockheed-Georgia Aircraft Co., Marietta, GA
COL J. Sabin	HQ MAC/LG	Scott AFB, IL
Mr. J. Sampson	OCC-ALC/DSTB	Tinker AFB, OK
Mr. H. Schuetze	DSTA	Kelly AFB, TX
Mr. H. Schumacher	2851st ABG/TD	Kelly AFB, TX
Sgt T. Schwino	2 MAPS/TRMC	Little Rock AFB, AR
COL F. Seltzer	OJCS/J4	Pentagon, WDC
Mr. H. Servais		Douglas Aircraft Co., Long Beach, CA
LTC F. Shapira	HQ 21AF/TRX	McGuire AFB, NJ
LTC L. Sherouse	HQ MAC/TRX	Scott AFB, IL
COL A. Shine	HQ MAC/XP-ACRA	Scott AFB, IL
CPT R. Simmons	USACACDA	Ft. Leavenworth, KS
SMSgt Simpson	HQ MAC/XPW	Scott AFB, IL
LTC Sledge	HQ MAC/TRXP	Scott AFB, IL
LTC G. Spivey	HQ MAC/TRXF	Scott AFB, IL
Mr. C. Sullivan	AFSCA/SAGM	Scott AFB, IL
CMSgt C. Swaney	463/DAW/DOXL	Kelly AFB, TX
LTC A. Swanson	HQ MAC/LGT	Scott AFB, IL
MSgt M. Swiderga	22 AF/TRP	Travis AFB, CA

<u>NAME</u>	<u>OFFICE SYMBOL</u>	<u>LOCATION</u>
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MSgt Ward	HQ MAC/TRXF	Scott AFB, IL
Mr. J. Ware	HQ USAF/XOOTA	Pentagon, WDC
Mr. B. Warren		Douglas Aircraft Co., Long Beach, CA
Mr. E. Watkins	WR-ALC/MMTVDA	Kobins AFB, GA
CMSgt M. Welch	DET4 HQ MAC/MACSO	Scott AFB, IL
MAJ J. Wells	USLAGC/MACLO	Fort Lee, VA
SMSgt W. Wetzel	HQ MAC/TRXM	Scott AFB, IL
MR. J. Wheeler	NRDC/STRNC-UST	Natick R&D Center, MA
MAJ R. White	HQ MAC/LG-R	Scott AFB, IL
TSgt D. Wiggins	HQ MAC/TRA	Scott AFB, IL
CMSgt D. Wilder	HQ MAC/LGTV	Scott AFB, IL
MSgt D. Wilks	2 MAPS/TRMV	Little Rock AFB, AR
TSgt R. Wilson	374 APS/TRMDC	Clark AB, Phillipines
MSgt R. Wilson	SA ALC/DSTA	Kelly AFB, TX
LTC J. Winter	HQ USAF/LETN	Pentagon, WDC
LTC L. Wood	DAMO-FDQ	Pentagon, WDC
LTC L. Yarbrough	436 APS/TRO	Dover AFB, DE

Appendix E LISTING OF REFERENCES

LISTING OF REFERENCES

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